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ALPHONSE FTELEY.

Member, Boston Society of Civil Engineers.
Past-President, American Society of Civil Engineers.

JOURNAL

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A CENTURY'S PROGRESS IN ENGINEERING EDUCATION IN THE UNITED STATES.

BY ROBERT HEYWOOD FERNALD, MEMBER ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, February 18, 1903.*]

THE past century has been a period of special significance in the development of technical education, and is properly regarded as the era of its most important advancement. Reviewing the history of this period, we find ourselves, even at its beginning, a long way from the original source of technical education, which is, in fact, prehistoric. A brief sketch of the earliest known results of this type of education is of value as revealing the foundation of its more recent accomplishments.

The Bible states that Tubal-Cain, the inventor of the art of forging metals, was "an instructor of every artificer in brass and iron"—and this nearly 4000 years B.C. The building of the great cities of the ancients required a knowledge of materials and methods of construction which seem marvelous to-day, and manufacturing and other industries must have formed a necessary part of the evidently active life of ancient communities. The cutting of the great monoliths from the quarries of Syene, together with the inscriptions wrought upon their faces; the raising of these huge masses of stone to form the pyramids; the building of great tombs in these structures, as well as the excavating into the mountains of the region for a like purpose, and the application of the mechanic arts in ways more refined and delicate, but nevertheless enduring, lead directly to the conclusion that the foundation of technical training and a knowledge of technical principles are as old as civilization; and in tracing the history of engineering

*Manuscript received June 6, 1903.—Secretary, Ass'n of Eng. Socs.

education in any country one is taken back to the ancient cities of Assyria, Babylonia, India, Egypt, Greece or Italy.

Some 1500 years B.C. a great university, supported by the Pharaohs, is shown to have existed by records since found. Dormitories, for those able to pay the necessary fees, were erected. Over eight hundred instructors were enrolled as members of the faculty, and schools of art, painting, sculpture, architecture and engineering, so far as developed, were included within this wonderful institution.

As early as 1300 years B.C. the University of Rameses was planned, and one thousand or more years later the great University of Alexandria was founded. In this latter university technical education seems to have been a more prominent feature, and more than ever before was there an effort to give instruction in all the forms of the arts, literature and sciences, and the modern sciences can easily be traced back to these ancient efforts. The work of Plato, Aristotle, Archimedes and Euclid was directly in the line that eventually developed into the various technical branches. These men and their associates had much to do in originating and investigating the scientific theories of that day, and many of their conclusions have stood the tests of time.

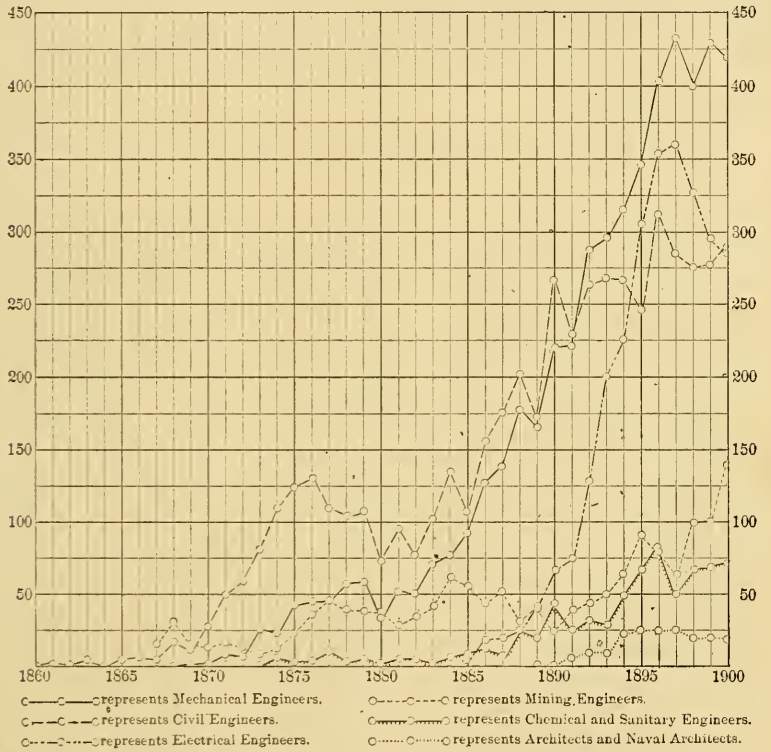
It was Galileo who, in 1590 A.D., ventured to question the possible mistakes in Aristotle's statements, and to him dynamic engineering owes its possibility. To the priest and monk is due the credit of having kept alive the mechanic arts during many centuries, for it was through the church that educational movements and developments were kept from total destruction.

What is to-day called the new education is really not new, but simply a recent revival and development of an education which dates back many hundred years before the Christian era; for, as Riedler has said in disputing the fact that medicine was the oldest science, "older still is technical development: civilization began with man."

It is not the purpose of this paper to trace the development of engineering education as a whole, but rather to note the progress of such education in the United States.

Before beginning the historical portion which applies to the United States alone it is of interest to inquire what is regarded as the proper education for an engineer, and later to observe, as far as space will permit, the conditions prevailing in the technical institutions of this country, to ascertain whether these institutions are doing all in their power to meet the educational demands of the present generation of engineering students.

To educate her youth should be one of the highest privileges of any state. Whether in peace or in war, the engineer is found to be an indispensable factor in a nation's efficiency. Naval battles are fought by the engineer, the manipulation of the land forces is possible only through the work of the engineer, and, in times of peace, manufacturing, commerce, and, in fact, nearly all the arts and sciences depend upon the engineer. What is more natural than the tendency of a large percentage of the young men of to-day to train themselves along the lines offering such vast opportunities?



NUMBER OF GRADUATES IN THE SIX ENGINEERING DEPARTMENTS FROM 1860 TO 1900, INCLUSIVE.

What, then, should be the nature of this education? Should the engineer be a specialist only, or should he have a broad and liberal education coupled with special training?

Ruskin says that "An educated man ought to know these things: First, where he is—that is to say, what sort of a world he has got into, how large it is, what kind of creatures live in it, and how; what it is made of, and what may be made of it. Secondly, where he is going—that is to say, what chances or reports

there are of any other world. Thirdly, what he had best do under the circumstances—that is to say, what kind of faculties he possesses; what are the present state and wants of mankind; what is his place in society, and what are the readiest means in his power of attaining happiness and diffusing it. The man who knows these things and who has his will so subdued in the learning of them that he is ready to do what he knows he ought, is an educated man, and the man who knows them not is uneducated, though he could talk all the tongues of Babel." Even after settling to his own satisfaction these three conditions of Ruskin it is still a difficult question for a young man to determine what should be his courses of study best to prepare him for the greatest usefulness and the highest possibilities.

It must be borne in mind that an education is not a collection of facts stored away, to be drawn upon as desired and used as mere facts with no development or improvement, but rather a condition of the mind which enables one to develop systematically and symmetrically such problems and conditions as may come before him for solution or investigation. This, it seems, marks the distinction between a special and a liberal education, the one giving a supply of facts and information, the other teaching the student to use his own powers of observation and judgment. It is Huxley who so well defines the liberally educated man. He says: "That man, I think, has a liberal education whose body has been so trained in youth that it is the ready servant of his will, and does with ease and pleasure all that, as a mechanism, it is capable of; whose intellect is a clear, cold logic engine, to be turned to any kind of work and to spin the gossamers as well as forge the anchors of the mind; whose mind is stored with the knowledge of the great fundamental truths of nature and of the laws of her operations; one who, no stunted ascetic, is full of life and fire, but whose passions have been trained to come to heel by a vigorous will, the servant of a tender conscience; one who has learned to love all beauty, whether of nature or of art, to hate all vileness, and to esteem others as himself."

This powerful description applies with equal force to the engineer, the clergyman or the man of letters, and no one aiming toward a life of great usefulness and power can question the superior strength and nobility of him who is able to follow such a course as shall develop as completely as the natural endowment of the individual will allow the broad, well-balanced and liberally educated man. This broad, liberal education produces a truer conception of the truth of existing laws, the application of better

judgment in thought and a clearness of apprehension and comprehension not possible in the case of the recipient of a narrow special education.

The engineer should be a man of large conceptions and sound judgment, with a thorough knowledge of the truths of nature and the ability to convert the results of her laws into channels best adapted to the needs at hand. His resources must be unlimited. His associations are such that culture and refinement are of great moment, and a well defined knowledge of the conditions and resources of the world at large is indispensable. Business training is also very essential, and, in fact, there is probably no other profession in which the cultivating influences of a general education are more necessary than for the man who has to cope with the greatest problems of civilization and progress—the engineer.

Is it possible for the average student of engineering to obtain such an education? It is, of course, necessary for him to be conversant with his special lines, and the average time taken for a college education will not admit of thorough training in one particular direction as well as years of unknown value that may be devoted to general and culture subjects. What the proportion should be and the order and relative value of different subjects is outside the province of this paper, but it will prove of interest to note later the general tendency, in this regard, of the engineering institutions of the United States. The more one studies the subject, the more information one gathers from those in positions of responsibility, and the more one watches the careers of young men, the more convinced does he become of the misfortune which has befallen those who have neglected the cultivating influences of such educational advantages as were within their reach. It is true that many a young man, through force of circumstances, cannot avail himself of the opportunities for such education, and is forced to fight his own way as best he can, securing only, if any at all, such special training and education as will best fit him for his particular chosen profession. Such a young man is unfortunate, but not to be blamed, and may far outstrip, both in natural ability and application, the young man of more desirable opportunities who has ignored his chances for development.

Misfortunes and difficulties do not necessarily strengthen a man. The strong man only can overcome such obstacles, and while he may, by virtue of his strength, accomplish much, yet it is a question whether the same man with such qualities would not have been even greater had he been allowed the opportunities and

privileges of a better and more liberal education. Much more estimable, however, is the man who has come up under such hardships than he whose ease and luxury have killed worthy ambition and have made the want of the best possible education a matter of indifference and neglect. In speaking of a liberal education, President Timothy Dwight, of Yale, has said: "He may not be a philosopher, or a poet, or a statesman, or a scholar; but as educated, and because he is educated, he is thoughtful, rich in his resources for himself and for others. This is what the higher education means, and it has no truest and deepest meaning apart from this. This developed power of serious thought is the essence of educated life. It is the fountain of living water within the mind, which is for every educated man the blessing of such life. To have rich thoughts, serious thoughts; in the sense of calm, serene, earnest, intelligent, cultured, generous, manly thinking on any and all themes which are worthy of human thought, what blessing for the mind can be greater, or can contain in itself more truly the secret of the best living?

"Who knows that results are greater when the man understands only one thing and thinks only one? The results that are seen may, perchance, be greater; though this, as relating to all cases, will need proving. But those that are unseen, who can tell of them? And the unseen results are often, if not always, the greatest and most important. In the unseen region is influence. It is itself, in the largest working and measure of it, the most unseen of all things. But what influence is, and from the nature of influence will ever be, so wide reaching as that of a rich mind and soul which are filled out by education on every side to their fullness of culture and beauty?"

Never has the lack of a college education been more keenly felt than by the young men of the present day who have either neglected opportunities or have been prevented from securing those advantages which are so gratifying to the educated and which money cannot buy. Sympathy is indeed due the young man who feels his lack of appreciation and knows his limitations to be due to the want of a proper education. Very few there are who would not give all they possess, when they realize their limitations, to feel that they had the power to discuss the momentous problems of the day with the educated and prominent men of the land, or could at least carry on a pleasing conversation with men of deep thought and keen perception. If in addition they can acquire the ability to appreciate the best literary, musical and artistic productions, the sacrifice is great that will not be made for such an end.

"The more one has the more one wants" is strikingly true in educational circles, and it is a question whether the average young man without a college education feels more keenly his lack than does the young man who has risen relatively higher, but has pursued a single narrow line, leaving out the subjects which tend to broaden his views and to open for him vast possibilities in the world of refinement and culture, because his absorption in the work of his own special field has entirely shut them from view. When he awakes to find himself far behind his more fortunate fellows, then he catches glimpses of the great opportunities that might have been his, had he but realized earlier the difference between the educated man and the man whose whole aim and study have been crampd into one narrow line. This is not saying that the specialist is not needed, and to-day more than ever before, but the specialist whose educational foundation is broad and liberal, who is a well-rounded man, who can appreciate the necessity of, and understand, in a general way, the work of others in fields which are possibly very remote from his own, is a man of larger resources and possibilities, and is a much greater power in the world than the mere specialist can be. His own special line need not suffer on account of his broad conception of life and study, but, on the contrary, the deductions and results of his specialized efforts will bear a truer and more direct relation to existing facts and conditions than otherwise would be possible. The following words from Bishop Henry Potter, delivered at the one hundredth commencement of Union College, at Schenectady, carry out this thought: "The time will never come when a man who has not merely learned certain chemical combinations so that he can manufacture a fertilizer, or certain mathematical combinations so that he can build a railroad, but has also learned what made a little peninsula in the Adriatic the mistress of the world, or how Roman law became the basis of the jurisprudence of Christendom, or how the fall of empires was foreshadowed in the 'Republic' of Plato, or how the growth of a corrupt and privileged ecclesiasticism brought about the transformation of modern Europe, the time will never come, I say, when the man who has learned these things, not a parrot-like learning, but in the length and breadth of their vast and enduring significance, will not be, in every highest sense, the master of him who has not."

Literature, languages, philosophy and mathematics do not make the well-rounded, cultured man any more than do special technical courses. The field of information and training is unlimited, and there is no one field or branch so broad that great

advantage cannot be gained by investigation in the others, and that man may count himself fortunate whose early years are well directed and well employed in the serious pursuance of study in the courses best fitted to develop and mold "the man," for that training is indisputably the most noble and most desirable which has for its aim the development of those faculties and powers which shall first make the student a man, and secondly fit to undertake work in his special lines.

To what extent this idea has been carried out by the engineering institutions of the United States can be shown only by a sketch of the growth of such institutions, and by observing the demand for and the success of young men whose lives have been molded in these engineering schools. The healthy growth of the technical school is marked with keen interest, and the following brief sketch of its development during the past century shows at once the imperative need of such institutions and the excellent quality of their work, together with the fact that progress in engineering education has kept pace with the development of the country.

At the very beginning of the nineteenth century the need of engineering education was felt, and the United States Military Academy at West Point, being the only institution fitted to give such training, took the initiative and in 1802 conferred degrees upon the first two engineers graduated in the United States.

*A few years later an effort toward engineering education was made by Thomas Jefferson, and, although he was unable to secure the carrying out of his plans, it is of interest to note his advanced ideas upon this subject, for in 1818 he included in an outline of the scope of higher education this expression: "To harmonize and promote the interests of agriculture, manufacturing and commerce, and to enlighten our youth with mathematical and physical sciences, which advance the arts, and administer to the health, the subsistence, and comforts of human life."

In attempting to organize the University of Virginia he so planned that four of its ten courses should be scientific. He spoke of it as "a school of technical philosophy" and desired instruction in "the sciences of geometry, mechanics, statics, hydrostatics, hydraulics, hydromechanics, navigation, astronomy, geography, optics, pneumatics, acoustics, physics, chemistry, natural history, botany, mineralogy and pharmacy," and also in writing of his plans said: "The use of tools, too, in the manual arts is worthy of encourage-

*NOTE.—Much of the following historical portion of this paper was taken from articles published in *Engineering News*.

ment by facilitating to such as choose it an admission into the neighboring workshops."

So closely allied with engineering training are the schools of manual training that the mention of the founding of the early schools is of interest historically. Probably the first institution of this class in the United States was organized in 1833 at Penfield, Ga. It was conducted by the Baptist church and was known as Mercer Institute. Prof. J. J. Wilmore, in writing of "Some Phases of Engineering Education in the South," adds in reference to Mercer Institute: "A student at that time, writing many years afterward, feelingly says: 'The work was on the farm. There was also a sort of mechanical department. A preacher thirty years old, parrot-toed, a carpenter—he bossed it. For a long time I worked at the whipsaw.'" This institution was followed by Wake Forest Institute the next year.

Not long after this a great advance in higher technical education was made, for in 1840 Rensselaer Polytechnic Institute, of Troy, N. Y., came to the front with the first civil engineers to be graduated, not only in the United States, but in any English-speaking country,—graduating a class of thirteen that year.

The opportunities of obtaining training in engineering lines previous to this time were very limited, as the only institution giving any such instruction was at West Point, and the only other means of obtaining any such education was by entering the office of some civil engineer. As this latter system "existed in New England, no formal articles were drawn, but the arrangement was understood to be for three years, during which period the student was charged $100 per year for his 'tuition' and was credited with the liberal sum of 12½ cents per hour for actual work in the field, office work being gratis." The terms varied at times, particularly "after the war," when office work received the same compensation as field work. The student was allowed to ask questions and to pick up what information he was able.

Previous to 1850 the important engineering positions were held largely by graduates of West Point, but since the establishment of the institutions especially adapted to give instruction in engineering lines this institution has furnished few engineers. Of the first thousand graduates of West Point some one hundred and fifty became civil engineers, but of the second thousand, only fifty, and since the class of 1863 few have become civil engineers of prominence.

The condition of the country prior to 1840 was such that there was little demand for engineers. There were practically no railroads and the general development was not such as to require the services of such men to any extent, outside, possibly, of the canals.

In founding Rensselaer Polytechnic Institute Hon. Stephen Van Rensselaer did much for the cause of engineering. The institution was founded by him in 1824-25, but in the first copy of the act of incorporation and in the constitution and laws of the school the word "engineering" or "engineer" does not appear. In 1828 these words made their appearance, as the senior professor was to lecture on "Chemistry, Natural Philosophy, Geology, Land Surveying, and Civil Engineering." It was October 14, 1835, that the first prospectus in English of a school of civil engineering was issued. Among other things it stated that the degree of civil engineer would be conferred upon "candidates of seventeen years and upwards who are well qualified in that department." "One year is sufficient for obtaining the Rensselaer degree of Bachelor of Natural Science, or of Civil Engineer for a candidate who is well prepared to enter. Graduates of colleges may succeed by close application during the twenty-four weeks in the summer term. Candidates are admitted to the Institute who have a good knowledge of arithmetic and can understand good authors readily, and can compose with considerable facility." "The degree of Master of Arts is conferred after two years of practical application." Rensselaer graduated from six to thirteen engineers a year, and these, with the few from West Point, made up the list of directly trained engineers for a period of some ten years, when the school of engineering of Union College entered the field in 1845, with the distinction of being not only the second engineering school, but the first to be organized as a branch of a classical college. The success of this institution was not marked, as it graduated only two or three students of engineering a year for a long period and remained very small until about 1860.

In 1846, the year following the organization of the engineering department of Union, the Lawrence Scientific School became a branch of Harvard University, and was the third institution to introduce engineering. The history of this institution has been until within a recent period most unfortunate, and in referring to it some writer has said: "By others' faults wise men correct their own, and as an example of the noble art of how not to do it, it is perhaps without a parallel." The conception of Hon. Abbott Lawrence, the donor, was exceptionally fine, and had his wishes in the matter been fulfilled the history of the engineering department of Lawrence Scientific School might have been very different. The following extracts from his letter of donation leave no doubt as to his personal views and wishes. He desired it to be "a school for

the purpose of teaching the practical sciences." There existed a "pressing want of an increased number of men educated in the practical sciences" or in "the practical applications of science." He desired the school to "educate our engineers, our miners, machinists, and mechanics." He further says: "I have thought that the three great branches to which a scientific education is to be applied amongst us are, first, engineering; second, mining, in its extended sense, including metallurgy; third, the invention and manufacture of machinery."

In 1849 Prof. Henry L. Eustis, second lieutenant of engineers, was appointed professor of engineering, and gave for some years very excellent instruction, and the failure of the school to live up to the wishes of Mr. Lawrence was in no way due to Prof. Eustis. The money was devoted to various other branches, and after his death no professor was appointed, and Harvard, in failing to live up to the letter of the bequest, forfeited an opportunity of having one of the most successful engineering departments of this country.

In spite of lack of funds and demands in other directions, the engineering courses had been established, and the first class of four was graduated in 1853. For a few years the school prospered, but in 1859 the decline began. Prof. Eustis went to war and returned much out of health and unable to fill the position. He died in 1885, and the engineering department disappeared for some time. Finally, under the guidance of Prof. W. S. Chaplin, followed by Prof. N. S. Shaler, as dean of the scientific schools, and Prof. I. N. Hollis, now professor of engineering, the department is coming to the front again, and Harvard may, even at this late day, partially redeem the unfortunate mistake made in disregarding the wishes of Mr. Lawrence.

In 1847 what is now Sheffield Scientific School of Yale University followed, but did little before 1852, and then was forced to economize in every way until 1859, when Mr. Joseph E. Sheffield reorganized the school. As an engineering school it did not get well under way before 1861, but the possibilities of this progress were brought about by earlier efforts, and much credit is due the institution for having maintained an existence until Mr. Sheffield's interest was secured in its behalf.

By a bequest from Mr. Abiel Chandler, the Chandler School of Science and the Arts was founded in 1851 in connection with Dartmouth College for "a permanent department of instruction in the practical and useful arts of life," under which head Mr. Chandler mentioned particularly mechanical engineering, civil en-

gineering, carpentry, masonry, architecture, drawing and modern languages, "together with bookkeeping and such other branches of knowledge as may best qualify young persons for active life."

Located also at Dartmouth College is the Thayer School of Civil Engineering, founded by Brig. Gen. Sylvanus Thayer, U. S. A., who was graduated in 1807 from Dartmouth and founded the Thayer School in 1867.

To Michigan belongs the honor of starting the first engineering school on other than private donations, and upon an equal footing with the other departments of the university. This was done in 1852 at the State University, and the first degrees of civil engineer were granted eight years later—1860. Michigan may well claim the distinction of founding the second strong engineering school in the United States, and this in the face of the poor and unsettled condition of the state prior to 1860.

No other institution giving engineering courses appeared until Brooklyn Polytechnic began graduating students in 1866, and this was soon followed by the Columbia College School of Mines, which was the first school of mines organized in America, although Michigan graduated a class the same year, 1867, and the Massachusetts Institute of Technology followed a year later.

To Prof. Thomas Eggleston belongs the honor of being the pioneer in organizing a school of mines. His plans for Columbia were made in 1863 and he was appointed professor in 1864. In speaking of the School of Mines at Columbia, the writer in the *Engineering News* says: "It needs only to add a course in mechanical engineering and the school will cover as broad a field as any other, and a broader than most." The course in mechanical engineering has now been added, and the School of Applied Science is in excellent condition.

The next institutions to present graduates were the Massachusetts Institute of Technology and Washington and Lee University, in Virginia, both of which graduated classes in 1868. From its organization the Institute of Technology was recognized as a remarkably strong institution, and it is still looked upon as a leader among engineering schools. Much of the success in founding this institution is due to Prof. Wm. B. Rogers. The organization meeting was held on January 11, 1861, and the act of incorporation gave the institute and the Boston Society of Natural History the site occupied by the buildings, two-thirds for the institute and the other third to the Society of Natural History.

Owing to the War of the Rebellion the school was not started until 1864, and meantime the Land Grant Bill—to be discussed

later—had been passed, and the Massachusetts Institute of Technology received a portion of the aid from this act. A class of thirteen was graduated in 1868. The first catalogue showed a list of seventy-two students, nearly all from the field that should have been covered by Lawrence Scientific School had that institution but taken advantage of its opportunities. The six courses originally outlined by Prof. Rogers have formed the basis of instruction, although others have been added from time to time. The institution has been most prosperous, and has proved a credit not only to Boston and Massachusetts, but to the country.

Since 1862 a large number of institutions having engineering departments have been organized, many of which resulted from the Land Grant Bill. Between 1865 and 1870 as many as eighteen were founded.

Stevens Institute, organized in 1871, has the distinction of giving instruction in mechanical engineering only, and of conferring but one degree, that of mechanical engineer.

Probably no other single act has done more to advance the possibilities of engineering education than the bill introduced into Congress by Hon. Justin Morrill, of Vermont, and commonly known as the Land Grant Bill. The original bill, introduced in 1858, was vetoed by President Buchanan, but in 1862 Senator Morrill again presented the bill, and on July 2d President Lincoln's signature made the bill a law.

Times were hard; the country was in a state of confusion and uncertainty; the interpretation of this law as passed was different in various states, and many sad mistakes were made during the history of the founding of these institutions. The conception was in itself wonderful, and, in spite of many serious mistakes on the part of the different states, a new era was opened to engineering education by the passage of the bill. The conditions of the law were that for each senator and representative in Congress the state should receive 30,000 acres of public lands, open for sale at $1.25 per acre, or instead each state was to receive scrip to be sold for the benefit of the state. For various reasons—misunderstanding of the law, a feeling of impatience or uncertainty, trickery or bad management—nearly all of the states failed to realize the full $1.25 per acre, and the majority received but a very small portion of this amount, one state receiving as little as 41 cents per acre. One state stands as a marked exception, viz., New York. Through the wisdom and caution of Mr. Ezra Cornell the investment was made to realize between $6 and $7 per acre on all but a small portion, which had been sold before Mr. Cornell secured control at

53 cents per acre. The result was that New York state received 42 per cent. of the amount realized from the total grant from her share of scrip, which was only about 10 per cent. of the total. The benefits resulting from the wisdom of Mr. Cornell have been most apparent in the progress of the excellent institution bearing his name. Nine states only succeeded in securing as much as the $1.25 per acre, and of these Tennessee received the least, $1.34½. The nine states to invest to good advantage were Tennessee, Wisconsin, Florida, Michigan, Iowa, Minnesota, California, Kansas and New York, the last three receiving more than $5 each per acre. These nine states received for 2,459,920 acres the sum of $10,633,860, while the remaining twenty-nine received for 7,117,920 acres only $5,232,512. Considering this most unfortunate start, the positions occupied by the various state institutions at the present day are most flattering, as each state has since endeavored to live up to the letter of the law, and has made up the initial loss to a certain extent by liberal appropriations from time to time. The clause of especial interest in the Morrill act refers to the use of the funds derived from the proposed sale of lands, and states that the income should be appropriated "to the endowment, support and maintenance of at least one college where the leading object shall be, without excluding other scientific and classical studies and including military tactics, to teach such branches of learning as are related to agriculture and other mechanic arts in such manner as the legislatures of the states may respectively prescribe, in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life."

The states accepted the responsibility and each state established its institution. In most states one institution only, including the courses in agriculture and the mechanic arts, was established, but Massachusetts made an exception, granting to the Institute of Technology, which was then coming to the front, a portion of the fund for its technical departments, the remainder going to establish the Agricultural College at Amherst. In a few states the fund was directed toward the development of the necessary departments in institutions already established. Thus came into existence a large number of colleges, the majority of which were to advance the interests of engineering education and many of which were destined to become leaders among the numerous universities of learning of the present day.

From time to time since the advent of these institutions, institutions founded by private funds have been organized, until to-day the opportunities for study in the varied lines of engineering are

so numerous and of such excellent quality as far to surpass the wildest dreams of the early promoters of such education. Not alone are there modern technical institutions where these various branches form the principal courses of study, but the old conservative universities have opened their doors and are striving to establish departments of engineering that shall rival those of the leading technical institutions.

The following statistics, secured directly from the institutions, serve to emphasize the wonderful progress that has been made. Although the list, of necessity, is incomplete, the general deductions are not seriously affected. Definite information was received from about 85 per cent. of the institutions giving technical instruction, and of the 15 per cent. from which no replies were received a few only could furnish information of material value in these deductions.

Many of the statistics for the civil, mechanical and mining departments prior to 1890 were taken from articles published in the *Engineering News* for 1892, thus saving much annoyance to the institutions that kindly filled the remaining blanks.

No attempt has been made to supply the desired data from the catalogues of the colleges from which no replies have been received. While in some cases this might be done to advantage, yet in general the results would be far too inaccurate to add value to these records.

Considering the courses offered, the returns show that at the close of the nineteenth century about 70 per cent. of the institutions considered offer a course in civil engineering, 64 per cent. offer mechanical engineering, while electrical engineering follows closely, being offered by nearly 60 per cent. Mining engineering is the only other course given by any large number of institutions, some 34 per cent. reporting such a course.

Architectural departments are listed from about 17 per cent. of the institutions, and it is interesting to note that fully half of the architectural courses were established within the last ten years of the century. Naval architecture has but recently entered the field, but three institutions reporting courses, Cornell University having established a course in 1890, the Massachusetts Institute of Technology in 1895 and the University of Michigan in 1900. Courses in chemical and sanitary engineering seem also to be limited in number, but six institutions reporting courses in the former and four only in the latter.

It is of interest to note the increase in the total number of graduates of the eighty colleges represented for the last twenty years of the century. The total for 1880 is lower than for some

years previous and the increase from 1880 to 1885 should perhaps be modified. The eighty colleges considered graduated from engineering courses:

	No.	Increase.	Per cent. Increase.
In 1880	148	...	...
In 1885	269	121	82
In 1890	618	349	130
In 1895	1,076	458	74
In 1900	1,217	141	13

The accompanying diagram shows the number of graduates from each department for the forty years from 1860 to the close of the college year of 1900, together with the fluctuations from year to year. Owing to the fact that among the few institutions from which no replies were received are one or two that graduated several civil engineers in the early sixties, the curves shown are somewhat lower than they should actually be for the first five or ten years. This, of course, may be said to be true of the actual figures for each year, but the percentage of error is very small after the first few years, and the curves show without perceptible error the relative growth of the different departments.

Perhaps the first point of interest in the diagram is the decrease in the number of graduates in the late seventies, which is accounted for by the panic of '73, the reduced number to enter the years of the financial depression causing the small number to graduate four years later. After recovering from this depression the number of graduates in mechanical engineering increased rapidly, with occasional minor fluctuations, until affected by the depression in the financial market of '92-'93.

From about '83 to '90 civil engineering had a prosperous growth, but from '90 to '95 a serious falling off in the number of graduates is observed. Ninety-six saw a decided improvement, which was necessarily cut short by the results of the hard times four years previous.

The number of graduates in electrical engineering increased from the first with remarkable rapidity until the natural falling off in '96-'97. The growth in mining engineering has been small from the beginning, but the demand for the past ten years seems to be stimulating an advance of this department.

The closing decade of the century presents some very interesting statistics, as noted below. In Table I is given the number of

classified students in engineering courses* in 1889-90 and in 1899-1900 in the eighty colleges from which returns were received.

TABLE I.

	1889-1890.	1899-1900.	Increase.	Per cent. Increase.
C. E.	1,647	2,432	785	48.0
M. E.	1,345	2,935	1,590	118.0
Mn. E.	599	1,441	842	140.0
E. E.	855	1,960	1,105	129.0
S. E.	7	16	9	13.0
Ch. E.	21	16	5	24.0
A.	268	299	31	11.5
N. A.	....	51	51	...
Totals	4,742	9,150	4,408	93.0

These figures do not in most cases include the first-year men, as in but few institutions are the courses determined before the second year.

In like manner Table II presents the number graduated in engineering courses in 1890 and in 1900 from the same eighty colleges:

TABLE II.

	1890.	1900.	Increase.	Per cent. Increase.
C. E.	265	287	22	8
M. E.	219	418	199	91
Mn. E.	25	139	114	456
E. E.	66	283	217	329
S. E.	....	4	4	...
Ch. E.	....	15	15	...
A.	43	62	19	44
N. A.	....	9	9	...
Totals	618	1,217	599	97

The percentages both in Tables I and II show, for the most part, very satisfactory increases. The increase in the number of graduates in mining engineering during the decade is certainly surprising. Although the increase in electrical engineering is very large, the result is not beyond expectations, as electrical engineering was in its infancy in 1890. Especial attention should be directed to the percentages of increase shown in the total attendance and total number of graduates in the engineering branches, Table I showing

*In the tables that follow, C. E. represents civil engineering; M. E., mechanical engineering; Mn. E., mining engineering; E. E., electrical engineering; S. E., sanitary engineering; Ch. E., chemical engineering; A., architecture; N. A., naval architecture.

the percentage of increase in attendance for the decade to be 93 and Table II that for increase in graduates 97, results which compare very favorably.

It is of interest to note the proportion of graduates to undergraduates, both in 1890 and 1900, as shown by Table III.

TABLE III.

PERCENTAGES OF GRADUATES TO UNDERGRADUATES.

	Per Cent. C. E.	Per Cent. M. E.	Per Cent. Mn. E.	Per Cent. E. E.	Per Cent. S. E.	Per Cent. Ch. E.	Per Cent. A.	Per Cent. N. A.	Per Cent. Total.
1890	16	16	4.2	7.7	..	..	16	..	13
1900	12	14	9.6	14.0	25	94	21	18	13

Glancing at the columns marked totals, it is seen that the ratio of the total number of graduates to the total number of undergraduates in the courses considered in the eighty institutions for 1890 and 1900 is exactly the same, the number of graduates being 13 per cent. of the number of undergraduates. Considering that the figures given for undergraduates are in most cases from three classes and the number graduating from one, this would indicate that the percentage of those taking these courses to graduate is about 39. This figure would be somewhat reduced were the first-year men considered, as the proportion to drop out during the first year is greater than during succeeding years.

It is hardly necessary to emphasize the fact that during this most healthy growth the standards of the various institutions have been constantly raised. This condition would naturally follow the general progress of the country as a whole, as well as the progress in engineering education.

Passing through the period when text-books were few, instructors poorly trained, illustrative apparatus and opportunities for research almost unknown, the engineering institutions awoke to find themselves among the leaders, with books of reference and text-books prepared by the best authorities; their instructors men of culture, experience and technical education; apparatus of the best, and, finally, engineering laboratories equipped for research work and practical illustration of the important principles and facts of engineering.

Of recent developments in connection with the advance of engineering education, the engineering laboratory is probably the most important. Such laboratories were proposed by Prof. W. B. Rogers about 1861, and in 1874 a steam engineering laboratory was established at the Massachusetts Institute of Technology. Prof. Channing Whitaker was placed in charge of this laboratory,

which was probably the first ever established. The influence of such laboratories has been very great, until to-day no institution of recognized standing in engineering can maintain a high position without well-equipped laboratories, as they are of the greatest importance as factors in instruction and training.

The development of some institutions to-day is such that they not only carry on their regular courses of instruction during the college year, but summer courses in the field, shop or mine are conducted, to give the student what practical experience is possible during his course of training. The regular recitations, lectures and laboratory work are supplemented by addresses by active men of experience and reputation, and by visits to manufacturing establishments and other places of interest for observation of the practical working out of the principles and methods of the classroom, together with the necessary modifications and changes to be made in formulas when applied to practice.

In addition to the regular undergraduate courses, some institutions are offering graduate courses in engineering, leading to the master's degree, and in some cases to the doctor's degree. Although the number of students pursuing graduate courses in technical lines is small, yet Table IV is not without interest, showing as it does the number of graduate students in engineering courses in 1889-90 and in 1899-1900 in the eighty colleges previously considered.

TABLE IV.

	1889-1890.	1899-1900.	Increase.	Per cent. Increase.
C. E.	32	45	13	41
M. E.	21	49	28	133
Mn. E.	17	35	18	106
E. E.	19	27	8	42
S. E.	..	..	..	..
Ch. E.	1	..	—1	—100
A.	..	2	2	..
N. A.	..	..	..	..
Totals	90	158	68	76

The sums spent annually upon the engineering institutions of this country are almost fabulous, yet the results seem to warrant such expenditure, for, judging from the past, much of the progress and welfare of the nation depends upon the successful education and training of its engineers.

An attempt was made to ascertain not only the annual tuition, but also the other fees that are charged to the student, and the annual cost to the institution per year per capita for running its

technical department. It was intended to determine as closely as possible the excess in the cost to the institution for each student over the amount received. Several difficulties have arisen in this effort, the chief one being that ten institutions only gave any figures regarding the cost per year per capita. The annual fees were found to be so variable that little of definite form could be obtained, but it seems that in most cases the fees are for materials used, or for breakage, and, with the possible exception of matriculation or graduation fees, the income and output would about balance. The ten institutions that reported upon the approximate cost per year per capita for running their engineering departments are listed below:*

COLLEGE.	Charge for Tuition.	Approx. Cost per Year per Capita.	Cost to Institution above Tuition.
Alabama Polytechnic Institute...	(R.) Free, (N.R.) $20	$25	(R.) $25, (N.R.) $5
Case School of Applied Science..	$100	350	$250
Colorado School of Mines.....	(R.) Free, (N.R.) $100	200	(R.) $200, (N.R.) $100
Kansas Agricultural College.....	Free	39	$39
Mass. Institute of Technology...	$200	335	135
Michigan College of Mines.....	(R.) $25, (N.R.) $150	385	(R.) $360, (N.R.) $235
Montana Agricultural College...	$12	150	$138
Rose Polytechnic Institute.....	75	350	275
Stevens Institute.....	(R.) $100, (N.R.) $225	275	(R.) $175, (N.R.) $50
Worcester Polytechnic Institute..	$150	290	$140

Of the sixty-six institutions reporting upon the amount of tuition, sixteen offer free tuition and seven others offer free tuition to residents but charge tuition to non-residents. In all thirteen of the sixty-six seem to discriminate between residents and non-residents.

About 20 per cent. of the institutions reporting charge at least $100, but not over $150, while only three receive more than $150, and each of these makes its tuition $200.† One institution, charging $100 for residents, advances its tuition to $225 for non-residents.

The development of the various departments of engineering has been closely connected with similar progress in the practical application of these branches in the engineering world. Which may be considered the result of the other is not definitely determined; that is, did the demand necessitate education in these special lines, or did the development of certain special features in the educational institutions lead to the discoveries and application of the new methods and processes? The two conditions are closely

*(R) indicates resident and (N. R.) non-resident.

†One institution has recently advanced its tuition to $250.

related, and it is probable that the one stimulated the other. In this connection Prof. F. R. Hutton has said: "It has been well pointed out that the industrial development of a country is progressive, and begins with a call, first, for the hunter and trapper; secondly, for the pioneer settler; thirdly, for the mining engineer and agriculturist; fourthly, for the civil engineer and specialist in transportation problems, and lastly, for the engineer who will develop manufacturing. It is presumed that this historical trend explains the development, throughout New England and the Eastern and Middle States, of the colleges and courses in mechanical and electrical engineering. It explains in part why one course catches up to, transcends and falls behind another, in spite of the best reputation, equipment and facilities of that other."

The recognized standing of the graduates of these engineering schools to-day is, without question, a great change for the better having taken place in the past twenty years, and to-day the technically educated man of ability is looked upon with favor by the officials of large corporations, and his position is practically assured. The very fact that he has to apply himself more closely and finds his course of training more rigorous than in the older courses for corresponding training in law, medicine or similar professions, has tended to place the work of the engineer upon a basis not only commanding respect, but making the profession a learned profession in the highest sense, for to-day no other department requires more work or a better quality of work of its students than is required of the student of engineering.

Possibly the most unfavorable criticism that can be offered concerning the present engineering school is its tendency to become too technical, in some cases not devoting the attention necessary for developing the man, as a man, in addition to developing him as a machine. The limited time at command and the extensive ground that must be covered make the avoidance of this tendency a serious question. The cultivation of those qualities which make "the man" is of the greatest importance, and should not be lost sight of in the endeavor to secure what appears to the average young man of immature development and restless ambition as the so-called "bread and butter" education. Unfortunately, there is a tendency on the part of many students in technical institutions to look upon general or culture subjects with disfavor, or at least with the thought that they are of no direct value in earning a living, and hence would better be left out of the course, or, if taken, should be regarded as secondary.

It is Pope who says:

"A little knowledge is a dangerous thing.
Drink deep or taste not the Pierian spring,
There shallow draughts intoxicate the brain,
And drinking deeply sobers it again."

The condition above referred to can be changed only by degrees. The experience of former generations will tend to correct this fault to some extent in the future, but the opportunity for direct improvement lies within the institutions themselves. Some institutions are at present fairly rigid in regard to requirements in courses of a purely general character, but with many these requirements are too easily modified, while with some, if not all, the tendency to specialize is so strong that the greater portion of the culture subjects have been forced from the curriculum.

The scope of this paper and the limited time at command will not permit a complete discussion of the correctness of courses as now arranged; the lack of training in English; the proper requirements for admission; the tendency to specialize in some institutions; the mistake, according to the writer's view, of granting the professional degree upon graduation, and other similar points which are deserving of careful study.

The results of the excellent work of these progressive institutions are readily seen in the great engineering feats of the past few years, in the growth and prosperity due to such achievements, in the accomplishments due to engineering training in our recent war, and one need only trace these results to their sources to be convinced that the engineering school of to-day is a powerful factor in a nation's civilization and development, as well as in the general progress of the world. For the men who are achieving these results are men whose earnestness of purpose and appreciation and respect for the laws governing existing conditions have been guided and strengthened by these institutions—institutions whose aim has been to develop serious thought, power to weigh facts, ability to probe the reasons and laws producing given conditions, a true respect for the opinions and judgment of others—a comprehension of facts and conditions as they exist to-day, and the power so to modify, improve or take advantage of these facts that new and better conditions and opportunities shall be open to him who enters the world to-morrow.

Herbert Spencer, in referring to the schools of England, might have referred with equal force to the schools of the United States when he wrote: "That which our school courses leave almost entirely out we thus find to be that which most nearly concerns the business of life. All our industries would cease were it not for that

information which men begin to acquire as they best may after their education is said to be finished. And were it not for this information, that has been from age to age accumulated and spread by unofficial means, these industries would never have existed." It is this very field that the engineering schools have filled and are filling so acceptably to-day. Their wonderful growth has exceeded all expectation, and the quality of their work has made for them a position surpassed in importance by no other educational development of the past century. No finer tribute to the work of the engineering school can be paid than the following from an address delivered by that able and noted educator, Gen. Francis A. Walker, at McGill University in 1893.

"The growth of scientific and technical schools on this continent during the past thirty years has savored of the marvelous."

"The notion that scientific work was something essentially less fine and high and noble than the pursuit of rhetoric and philosophy, Latin and Greek, was deeply seated in the minds of the leading educators of America a generation ago. And it has not even yet wholly yielded to the demonstration offered by the admirable effects of the new education in training young men to be as modest and earnest, as sincere, manly and pure, as broad and appreciative, as were the best products of the classical culture, and withal, more exact and resolute and strong. We can hardly hope to see that inveterate prepossession altogether disappear from the minds of those who have entertained it. Probably these good men will have to be buried with more or less of their prejudices still wrapped about them; but from the new generation scientific and technical studies will encounter no such obstruction, will suffer no such disparagement."

"The practical uselessness, for any immediate purpose, of a given subject of study may be no reason why it should not be pursued; but, on the other hand, the high immediate usefulness of a subject of study furnishes no ground from which the educator of loftiest aims and purest ideals should regard it with contempt or distrust. In either case, the question of real import is in what spirit the study is pursued."

"I know the scientific men of America well, and I entertain a profound conviction that in sincerity, simplicity, fidelity, and generosity of character, in nobility of aims and earnestness of effort, in everything which should be involved in the conception of disinterestedness, they are surpassed, if indeed they are approached, by no other body of men."

REDUCTION OF GRADE ON RAILROADS.

By C. D. Purdon, Member of the Engineers' Club of St. Louis.

[Read before the Club, May 6, 1903.*]

Since railroads passed the experimental and entered the commercial stage there has been a constant effort in all departments to devise means for operating with greater economy.

While much has been done to this end outside of the railroad proper, such as the production of rails, etc., by cheaper methods, what I refer to particularly is the actual moving of freight over the tracks; and one of the most important items of the cost of this service is the size of the train which can be hauled.

Probably one of the first steps toward cheaper service was the improvement of freight cars. Many of us can recollect when a freight car carried a paying load little, if any, greater than the weight of the car itself.

To-day we have, for heavy freight, cars carrying a load of 100,000 pounds, while the car itself weighs about 40,000 pounds.

Our locomotives have increased from the ancient style, with a weight of some 18,000 or 20,000 pounds on each of the driving axles (of which there were only two), to what may be considered as the present average freight engine of four driving axles, each with a weight of about 40,000 pounds.

It is true that there are in service such monsters as the Pittsburg, Bessemer and Lake Erie, with over 56,000 pounds on a driving axle, but such are exceptional.

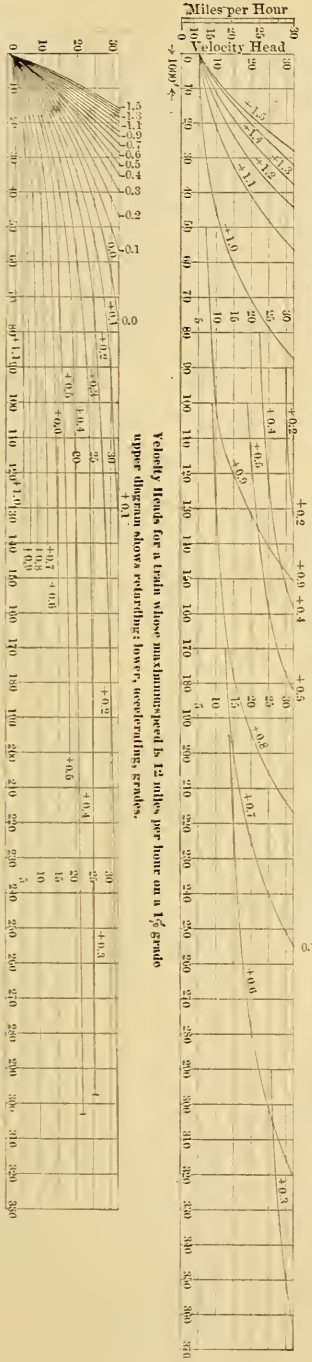
Such engines and cars have required the practical rebuilding of all our railroads, changing from 52 or 56-pound steel, without ballast, and Howe truss bridge, to rails of 75 pounds or over, 10 or 12 inches of ballast and heavy steel bridges with massive masonry substructures.

Statistics show that, with all the immense sums of money expended in these improvements, the cost of carrying freight has steadily decreased, thus proving the economy.

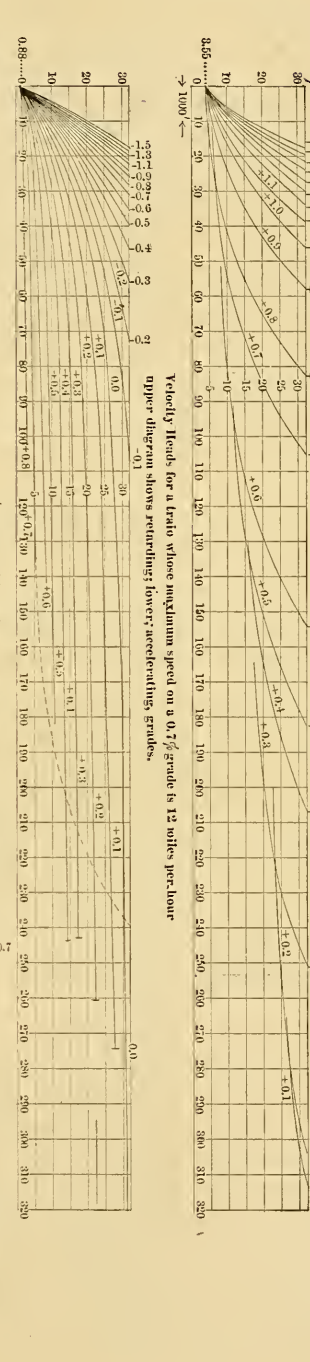
While it would be rash to prophesy that the size of engines and cars has reached a limit, it is certain that the development has reached a very high stage, and advances upon these lines in the future cannot possibly approach the developments already made.

With a view to further economy in train movement, the most promising field at present appears to be the reduction of the grades,

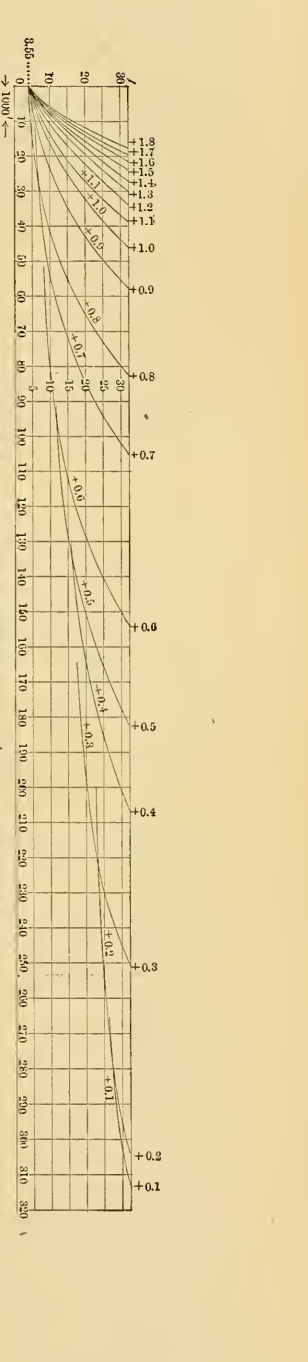
*Manuscript received June 6, 1903.—Secretary, Ass'n of Eng. Socs.

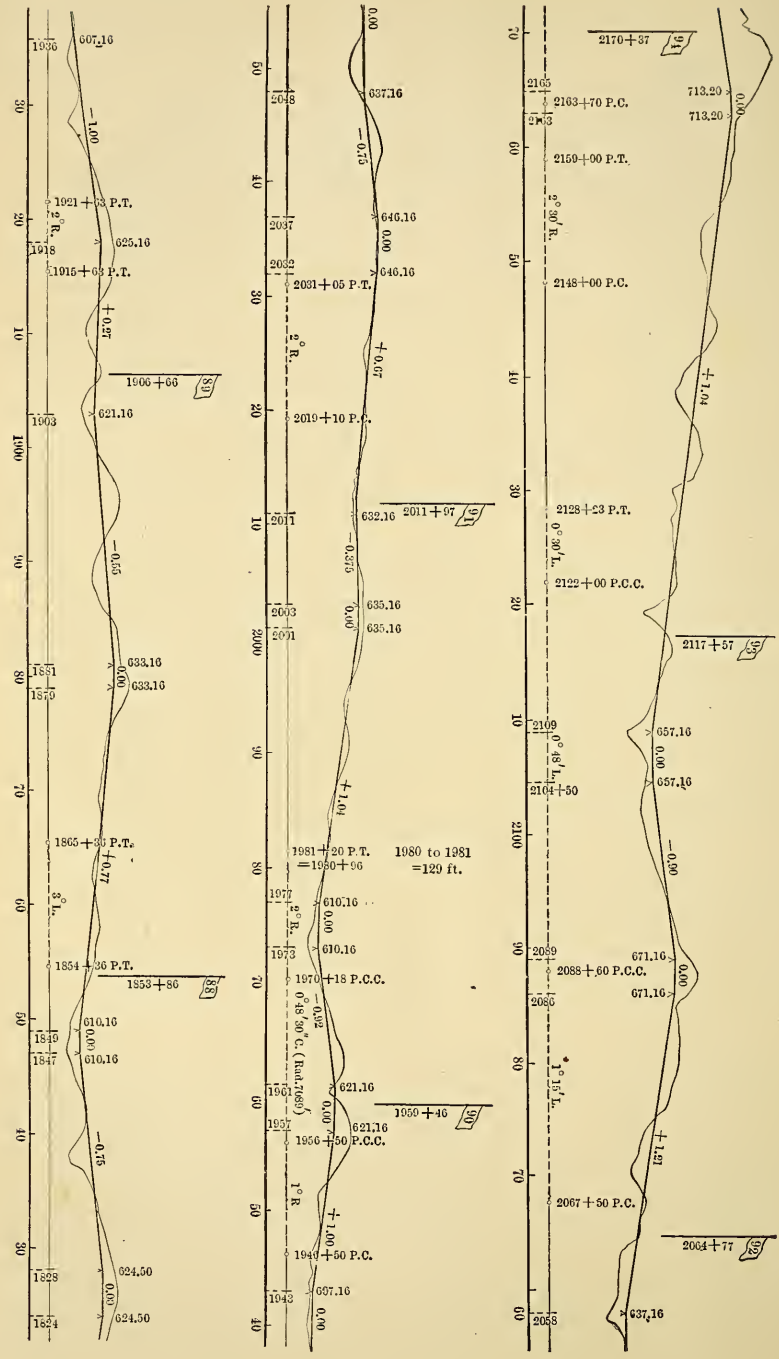


Velocity Heads for a train whose maximum speed is 12 miles per hour on a 1% grade
upper diagram shows retarding; lower, accelerating, grades.



Velocity Heads for a train whose maximum speed on a 0.7% grade is 12 miles per hour
upper diagram shows retarding; lower, accelerating, grades.




1936
607.16
−1.00
1921+63 P.T.
2° R.
1918
625.16
1915+63 P.T.
+0.57
1906+66
621.16
1903
1900
−0.55
1881
633.16
1879
0.00
633.16
1865+36 P.T.
+0.77
1° R.
1854+36 P.T.
1853+86
1849
610.16
0.00
1847
610.16
−0.75
1828
624.50
0.00
1824
624.50
0.00
637.16
2048
−0.75
646.16
2037
0.00
2032
2031+05 P.T.
646.16
2° R.
+0.07
2019+10 P.C.
2011
632.16
2011+97
−0.375
2003
0.00
635.16
2001
2000
635.16
+1.04
1981+20 P.T.
=1980+96
1980 to 1981
=129 ft.
1977
2° R.
610.16
0.00
1973
610.16
1970+18 P.C.C.
0° 48′ 30″ C. (Rad. 7069′)
0.52
1961
621.16
0.00
1957
621.16
1956+50 P.C.C.
1950+46
1° R
+1.00
1949+50 P.C.
1943
667.16
0.00
2170+37
2165
2163+70 P.C.
713.20
713.20
0.00
2159+00 P.T.
2° 30′ R.
2148+00 P.C.
+1.04
2128+23 P.T.
0° 30′ L.
2122+00 P.C.C.
2117+57
2109
657.16
0.00
0° 45′ L.
657.16
2104+50
−0.90
2089
671.16
0.00
2088+60 P.C.C.
2080
671.16
1° 15′ L.
+1.23
2067+50 P.C.
2064+77
2058
637.16

and as many of our principal railroads are already engaged in this work, and more are considering it, a short paper on the questions that arise upon the subject may be of interest.

It would of course appear, at first, that to take the profile and a straight edge and draw lines reducing the grades to those desired by cutting off the tops of the hills and raising the sags would be quite simple; and it would; but whether it would be the proper method is, at any rate, open to argument.

It has always been known that to "take a run at the hill" will help a train to surmount it; or, to speak more scientifically, that a train approaching a hill will ascend more easily the more speed it has attained before reaching the up-grade. This is taken advantage of by every train, and trains are made up on the basis of what the engine can get over the road with, ascertained by experience, and not from any calculations based on the grades shown by the profile.

The length of an adverse grade and the character and rates of the grades preceding it are more important than the actual rate per cent. of the grade itself, and it can easily be understood that a very long adverse grade, of a rate much less than the maximum, could limit the train load more than short grades of the maximum rate.

So that, to reduce grades over a division to the above mentioned ruling grade, perhaps 2-10 or 3-10 less than the maximum, would not enable an engine to haul an additional car.

Bearing this in mind, and also the fact that the train load will be what experience shows can be moved, it seems reasonable in grade reductions to take account of the velocity with which a train reaches an adverse grade, calculate how far up that adverse grade the stored-up energy and capacity of the engine will take the train, and begin reduction at that point instead of at the foot of the hill.

It does not follow that the grade showing the greatest rate per cent. is the ruling grade of a division or the grade that limits the weight of a train.

To get the best results for the least expenditure, therefore, it is necessary to make a study of each freight division and ascertain what effect each particular grade has upon a train, and then, by reducing the ruling or limiting grades, establish a virtual or equivalent grade for a division, which will be the limiting grade for trains, even if many of the grades show a greater rate per cent.

An objection may be made to this method on account of the possibility of a train having to stop from any cause on a grade

exceeding the virtual, and so be unable to start again without doubling the hill, but it is very questionable if this possibility will justify the very much greater expense of reducing all the grades, even if a train does get into trouble occasionally.

Many engineers have made rules for using the momentum of a train in an intelligent manner, and this paper is intended as a description of these rules and the method of use.

So far as the writer knows, the late Mr. A. M. Wellington was the first engineer to formulate rules establishing virtual grades, and he did establish, from brake tests and otherwise, the resistance of moving trains. His information has been greatly extended by others, notably by the engineers of the Southern Pacific, and, while many engineers differ in their methods, they reach practically the same results.

Suppose, for example, that a freight division has grades exceeding 1 per cent., and that it is desired to reduce to an equivalent 1 per cent. We must first study the profile for the effect each grade has upon the grade joining it and ascertain what momentum a train has at the beginning and end of each particular grade, and whether the momentum will enable the train to pass over the hill, or, if not, to what point on the hill it will assist, which point will be the place to begin reduction.

Certain points have been ascertained by Wellington, the Southern Pacific engineers and others. It is found that at each rate of speed the train has stored up energy enough to lift it a certain height, or take it a certain distance up an uprising grade if the engine only overcomes friction. This property is called the velocity head. It is also found what acceleration of speed or increase of velocity head is attained on a descending grade, the tractive power of an engine at various speeds and the resistance of the train in pounds per ton due to speed and to grade are also established.

Each engineer will choose his data for himself, but for sake of example the following will be taken:

Virtual ruling grade to be 1 per cent.

A stop to be made at each station.

A train to leave the yard limits at a speed of 5 miles per hour, or with a velocity head of 0.88 feet.

Weight of train to be such that the engine can maintain a speed of 12 miles per hour on a continuous ascending grade of 1 per cent.

Maximum speed of train to be 30 miles per hour, or velocity head 31.95 feet.

Minimum speed at top of hill, 10 miles per hour or velocity head of 3.55 feet.

We then make a table similar to Table 1.

The first column contains the speed in miles per hour.

The second column contains the corresponding velocity head, which will be used instead of the speed for convenience in calculating.

The third column contains the differences of the velocity heads in column 2.

The fourth column contains the tractive power of the engine in pounds per ton of train at various speeds, on the basis of an assumed power of 25 pounds per ton on ascending .1 per cent. grade at 12 miles per hour, of which 20 pounds is required for the grade and 5 for the speed.

The fifth column contains the resistance in pounds per ton due to the speed.

The sixth column contains the difference between columns 4 and 5, or the excess tractive power of the engine.

The seventh column gives this excess tractive power changed to grade at the rate of 20 pounds for 1 per cent. grade, grade being + or —.

We then take any rate of grade, and the algebraic sum of the grade considered and the equivalent grade in column 7 divided into the difference of velocity heads in column 3 will give the distance traveled by the train in passing from one rate of speed to the next higher. These distances are shown in column 8 for a — 0.4 grade, and column 9 gives the successive addition of column 8.

Columns 10 and 11 contain the same figures for a + 0.4 grade. These two grades are given as an example. It is, of course, necessary to calculate the two columns for each particular grade, + or —, which may be required, but it will be generally sufficient to use even 10ths.

All descending grades and all ascending below the maximum are accelerating up to a certain point. A train on an ascending grade of 1 per cent. will gain speed till it reaches 12 miles per hour, but a train at any greater speed will lose on an ascending 1 per cent. until it falls to 12 miles per hour, so that even descending grades may become retarding above a certain speed.

Column 11 shows the point at which a + 0.4 grade ceases to accelerate and begins to retard.

A diagram similar to that attached is then platted from the velocity heads and sums of distances for each grade, giving para-

bolic curves, the directions of which change as they change from accelerating to retarding.

For convenience the diagram is made in two parts, accelerating and retarding. It will be noted that many of the grades appear on both parts of the diagram.

When this diagram is made the study of the profile is begun.

A profile of about 7 miles of road is attached for an example, showing one grade of 1.21 and another of 1.04, neither of which is compensated for curvature.

We will compensate for curvature as follows:

Curves of 2 degrees and under, 0.03 per degree.

Curves over 2 degrees and under 5 degrees, 0.04 per degree.

Curves of 5 degrees and over, 0.05 per degree.

Suppose the train at station 1848 with a velocity head of 0.88 feet, it encounters a descending grade of 0.75 per cent. 1900 feet long. Entering the diagram we find, at the intersection of 0.75 and 1900, a velocity head of 26.5 feet. Then, taking 200 feet of 0.0 grade, with a velocity head of 26.5 feet, we get 27 at the foot of the + 0.77 grade; this 0.77 grade is taken as 536 feet of 0.77, 1100 feet of 0.89 and 1364 feet of 0.77 on account of curvature, and we find by continuing the use of the diagram that the train has a velocity head of 15 feet at station 1879.

The continuation of these calculations is given in Table No. 3, the first and second columns giving profile stations, third column the length of the grade, fourth column the rate of grade compensated for curvature (adding the compensating rate to ascending and deducting it from descending grades), and the fifth column the velocity head at each change of grade for westbound trains.

The seventh and eighth columns give the corresponding figures for eastbound trains.

It will be seen that a train loaded for 12 miles per hour on a + 1 per cent. grade will arrive at the top of the 1.21 grade with a velocity head of 9.5 feet (over 16 miles per hour), and at the top of the much longer 1.04 grade with a velocity head of 5.2 feet (over 12 miles per hour).

So that to reduce these grades to actual 1 per cent. would not enable us to increase the train load.

Table No. 2 gives the calculations to make a diagram for a train loaded for a maximum speed of 12 miles per hour on a continuous ascending grade of 0.7 per cent., and a print of the diagram is attached.

In Table No. 3 the sixth column gives the velocity heads for a westbound train, and column 9 the velocity heads for an eastbound

train, over the same profile as used above, using a virtual maximum grade of 0.7 per cent.

This shows that a train loaded for a maximum speed of 12 miles per hour on an ascending grade of 0.7 per cent. will fall to 10 miles per hour 200 feet short of the top of the 1.21 per cent. hill, and 2050 feet before reaching the top of the 1.04 per cent. hill.

Thus, to reduce these grades to a virtual 0.7 per cent. would only require changing the tops of these two hills as shown in red lines upon the profile.

Practically the 1.21 hill would not require reduction, but these figures are given for illustration of the method.

Having studied the profile in one direction, it is then studied in the other, and possibly changes will occur which may modify the first set of figures.

It is not necessary to discuss the best way of doing the actual work of grading, further than to suggest that if a grade requires raising any considerable amount, it is best to build a new line adjoining to avoid interference with traffic, building as close as possible.

As many roads have their embankments made from borrowed material, any considerable raise will fill the borrow pits, so that no earthwork is saved by trying to utilize the old bank.

It is doubtful whether a new road should be built on the momentum principle. On an old road water tanks, stations and other stopping points are fairly well established, while on a new road they are not. It might be well, however, to try and make the grade at tops of hills always less than maximum.

The cost of the actual work of reduction is a matter of estimating, and after the estimated cost of reduction has been obtained it becomes a question of whether it will pay to reduce.

All depends on the volume of business and the cost per mile of running a train, taking only such items of cost as are affected by the size of the train—mainly fuel, wages and train supplies, probably about 35 cents.

By reducing the grades we will increase the size and consequently decrease the number of trains and also the train mileage; and an extreme case might be supposed where much development of location was required for the reduced grade, in which the train mileage was increased more by the length of line added than it was decreased by the less number of trains.

Also the volume of business might be such that freight could not be held long enough to make up the larger trains.

Taking the present number of trains, adding prospective in-

TABLE I.

Speed. Miles per Hour.	Velocity Head.	Difference of Velocity Heads.	Tractive Power of Engine.	Train Resistance.	Tractive Power—Resistance.	Equivalent Grade.	−0.4 Grade. Distance.	−0.4 Grade. Total Distance.	+0.4 Grade. Distance.	+0.4 Grade. Total Distance.
5	0.88		29.60	4.50	25.10	—1.25	0.31			
6	1.26	0.38	28.94	4.55	24.39	—1.22	0.23	0.52	0.52	
7	1.71	0.45	28.29	4.60	23.69	—1.18	0.29	0.52	0.66	1.18
8	2.24	0.53	27.63	4.65	22.98	—1.15	0.34	1.86	0.81	1.99
9	2.83	0.59	26.97	4.70	22.27	—1.11	0.39	1.25	0.96	2.95
10	3.55	0.72	26.31	4.80	21.51	—1.07	0.49	1.74	1.26	4.21
11	4.30	0.75	25.65	4.90	20.75	—1.03	0.52	2.26	1.41	5.62
12	5.11	0.81	25.00	5 00	20.00	—1.00	0.57	2.83	1.62	7.24
13	6.00	0.89	24.35	5.20	19.15	—0.95	0.65	3.48	1.80	9.04
14	6.96	0.96	23.68	5.50	18.18	—0.91	0.73	4.21	2.34	11.38
15	7.99	1.03	23.02	5.80	17.22	—0.86	0.81	5.02	2.86	14.24
16	9.09	1.10	22.37	6.00	16.37	—0.82	0.90	5.92	3.43	17.67
17	10.26	1.17	21.71	6.20	15.51	—0.77	1.00	6.92	4.33	22.00
18	11.50	1.24	21.05	6.50	14.55	—0.72	1.10	8.02	5.63	27.63
19	12.82	1.32	20.39	6.80	13.59	—0.68	1.22	9.24	7.66	35.29
20	14.20	1.38	19.73	7.10	12.63	—0.63	1.34	10.58	10.61	45.90
21	15.67	1.47	19.07	7.40	11.33	—0.56	1.50	12.08	24.50	70.40
22	17.19	1.52	18.42	7.80	10.62	—0.53	1.63	13.71	50.66	121.06
23	18.79	1.60	17.76	8.20	9.56	—0.48	1.82	15.53	80.00	201.06
24	20.46	1.67	17.24	8.50	8.74	—0.43	2.01	17.54	23.85	23.85
25	22.20	1.74	16.71	8.80	7.91	—0.39	2.20	19.74	15.82	39.67
26	24.00	1.80	16.18	9.00	7.18	—0.36	2.37	22.11	12.86	52.53
27	25.88	1.88	15.66	9.50	6,16	—0.31	2.64	24.75	9.89	62.42
28	27.83	1.95	15.13	10.00	5.13	—0.25	3.00	27.75	7.80	70.22
29	29.86	2.03	14.60	10.50	4.10	—0.20	3.38	31.13	6.76	76.98
30	31.95	2.09	14.08	11.00	3.08	—0.15	3.80	34.93	5.97	82.95

Data for speed of 12 miles on 1 per cent. grade.

TABLE II.

Tractive Power of Engine.	Train Resistance.	Tractive Power—Resistance.	Equivalent Grade.	−0.4 Grade. Distance.	−0.4 Grade. Total Distance.	+0.4 Grade. Distance.	+0.4 Grade. Total Distance.
22.5	4.50	18.00	—0.90				
22.0	4.55	17.45	—0.87	0.30		0.81	
21.5	4.60	16.90	—0.84	0.36	0.66	1.02	1.83
21.0	4.65	16.35	—0.82	0.43	1.09	1.26	3.09
20.5	4.70	15.80	—0.79	0.49	1.58	1.51	4.60
20.0	4.80	15.20	—0.76	0.62	2.20	2.00	6.60
19.5	4.90	14 60	—0.73	0 66	2.86	2.27	8.87
19.0	5.00	14.00	—0.70	0.73	3.59	2.70	11.57
18.5	5.20	13.30	—0.66	0.84	4.43	3 42	14.99
18.0	5.50	12.50	—0.62	0.94	5.37	4.36	19.35
17.5	5.80	11.70	—0.58	1.05	6.42	5.72	25.07
17.0	6.00	11.00	—0.55	1.15	7.57	7.33	32.40
16.5	6.20	10.30	—0.51	1.28	8.85	10.63	43.03
16.0	6.50	9.50	—0.47	1.42	10.27	17.71	60.74
15.5	6.80	8.70	—0.43	1.59	11.86	44.00	104.74
15.0	7.10	7.90	—0.39	1.74	13.60	138.00	242.74
14.5	7.40	7.10	—0.35	1.96	15.56	29.40	29.40
14.0	7.80	6.20	—0.31	2.14	17.70	16.66	46.06
13.5	8.20	5.30	—0.26	2.42	20.12	11.43	57.49
13.1	8.50	4.60	—0.23	2.65	22.77	9.82	67.31
12.7	8.80	3 90	—0.19	2.95	25 72	8.28	75.59
12.3	9.00	3.30	—0.16	3.21	28.93	7.50	83.09
11.9	9.50	2.40	—0.12	3.61	32.54	6.71	89.80
11.5	10.00	1.50	—0.07	4.15	36 69	5.90	95.70
11.1	10.50	0.60	—0.03	4.72	41.41	5.48	101.18
10.7	11.00	—0.30	+0.01	5.36	46.77	5.09	106.27

Data for speed of 12 miles on 0.7 per cent. grade.

crease of business (if advisable) and the length of the division, the number of trains required will be found by taking the inverse ratio of the increased train load to the present load. This gives the

TABLE III.

Sta. to Sta.		Length.	Westbound.			Eastbound.		
			Grade.	V. H. 1%.	V. H. 0.7.	Grade.	V. H. 1%.	V. H. 0.7.
1828	1847	1900	—0.75	26.5	23.0	+0.75	23.0	19.5
1847	1849	200	0.00	27.0	23.5	0.00	32.0	32.0
1849	1854+	536	+0.77	24.0	21.0	—0.77	32.0	32.0
1854+	1865+	1100	+0.89	18.0	14.5	—0.65	32.0	32.0
1865+	1879	1364	+0.77	15.0	10.0	—0 77	32.0	28.5
1879	1881	200	0.00	16.0	11.0	0.00	23.5	16.5
1881	1903	2200	—0.55	32.0	28.0	+0.55	23.0	16.0
1903	1915+	1263	+0.27	30.0	25.0	—0.27	30.0	23 0
1915+	1918	237	+0.33	29.5	24.5	—0.21	19.5	17.5
1918	1921+	363	—0.94	32.0	29.0	+1.06	18.5	16.5
1921+	1936	1437	—1.00	32.0	32.0	+1.00	20.5	19.0
1936	1943	700	0.00	32.0	32.0	0.00	32.0	32.0
1943	1946+	350	+1.00	29.0	28.5	—1.00	32.0	32.0
1946+	1957	1050	+1.03	21.0	19.0	—0.97	32.0	32.0
1957	1961	400	+0.03	22.0	19.5	+0.03	25.0	21 0
1961	1970+	918	—0.90	32.0	29.0	+0.95	24.0	20.5
1970+	1973	282	—0.86	32.0	31.5	+0.98	29.5	28.5
1973	1977	400	+0.06	32.0	31.0	+0.06	32.0	31.0
1977	1980+	396	+1.10	28.5	27.0	—0.98	32.0	32.0
1980+	2001	1980	+1.04	15.5	11.0	—1.04	32.0	32.0
2001	2003	200	0.00	16.5	12.0	0.00	29.5	29.5
2003	2011	806	—0.37	22.5	17.0	+0.37	29.5	29.5
2011	2019+	810	+0.67	20.0	14.5	—0 67	32.0	32.0
2019+	2032	1290	+0.73	16.5	10.0	—0.61	32.0	32.0
2032	2037	500	0.00	19.0	12.5	0.00	27.0	25.0
2037	2048	1100	—0.75	30.5	24.0	+0.75	26.0	24.5
2048	2058	1000	0.00	31.0	25.0	0.00	32.0	32.0
2058	2067+	950	+1.21	21.5	15.5	—1.21	32.0	32.0
2067+	2086	1850	+1.25	9.5	16.50	—1.17	32.0	32.0
2086	2089	300	+0.04	11.0	7.0	+0.04	22.0	20.5
2089	2104+	1550	—0.87	30.0	24.0	+0.93	21.0	20.0
2104+	2109	450	+0.03	30.5	24.5	+0.03	32.0	32.0
2109	2128+	1923	+1.07	17.0	9.5	—1.01	32.0	32.0
2128+	2148	1977	+1.05	9.0	14.50	—1.04	32.0	32.0
2148	2159	1100	+1.11	6.0		—0.97	19.0	26.0
2159	2163	400	+1.04	5.2		—1.04	9.0	8.0

number of train miles saved annually, which, taken at (say) 35 cents and capitalized, will show the amount on which the economy of operation will pay interest.

It may be found, when the volume of business is fairly well settled, that a different virtual grade can be used in one direction from that used in the other.

EARLY AND CURIOUS TYPES OF THE CANTILEVER BRIDGE IN NEW ENGLAND AND NEW BRUNSWICK.

By Alfred W. Parker, M.E.

[Read before the Boston Society of Civil Engineers, March 18, 1903.*]

Mr. President and Gentlemen:

A few months ago, during a business call at a store on Oliver street, Boston, reference was made to the fact that about forty years ago Fort Hill was standing, Oliver and High streets then running over the top, the crossing being about 50 feet above the present grade. The proprietor then produced the photograph which you see here (Fig. 1), showing Oliver street cut through the hill to the present grade, with High street at the old grade and a wooden combination cantilever and bowstring girder bridge spanning the chasm. On showing the photograph to your president and telling him some particulars about the building of this and other similar bridges, both wood and iron, previous to 1870, he seemed to think the matter interesting as a bit of curious bridge history, and invited me to tell the story here.

The bridge shown in Fig. 1 was built in 1868 by the Solid Lever Bridge Company, a Massachusetts corporation, incorporated July 6th of that year. It was contracted for by the Street Department of Boston before the days of the present method of having all city bridges designed in the city engineer's department; otherwise, a veto would probably have changed a bit of this history.

The corporation name well describes the lever portions of the structure, which were *solid,* being built of 12 x 3 inch, spruce deal laid flat one upon the other and pinned together by wooden trenails. The shore ends of the two levers were started simultaneously on opposite banks. Floor beams were framed between and loaded with stone for the counterweights, and the levers were then built upward and outward, each course of plank, as laid, being projected beyond the previous one till the ends of the completed levers met in mid span. An arch built up of the same material was then added, the top portion of the lever acting as the chord or bowstring of the arch.

The floor line was at the top of the levers, the banks being cut down to receive the shore ends.

The originator of this curious structure was a very skillful

*Manuscript received July 2, 1903.—Secretary, Ass'n of Eng. Socs.

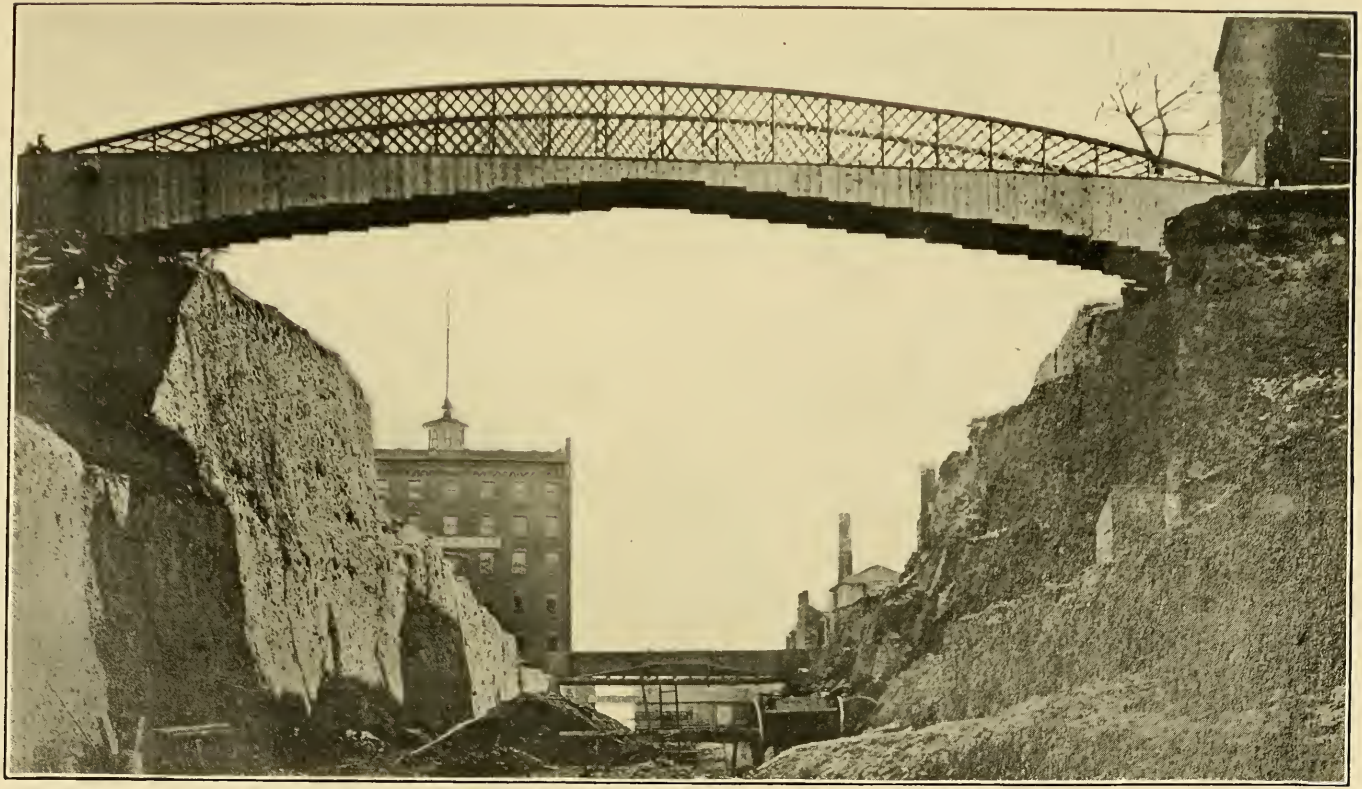


Fig. 1. High Street Bridge, over Oliver Street, Boston.

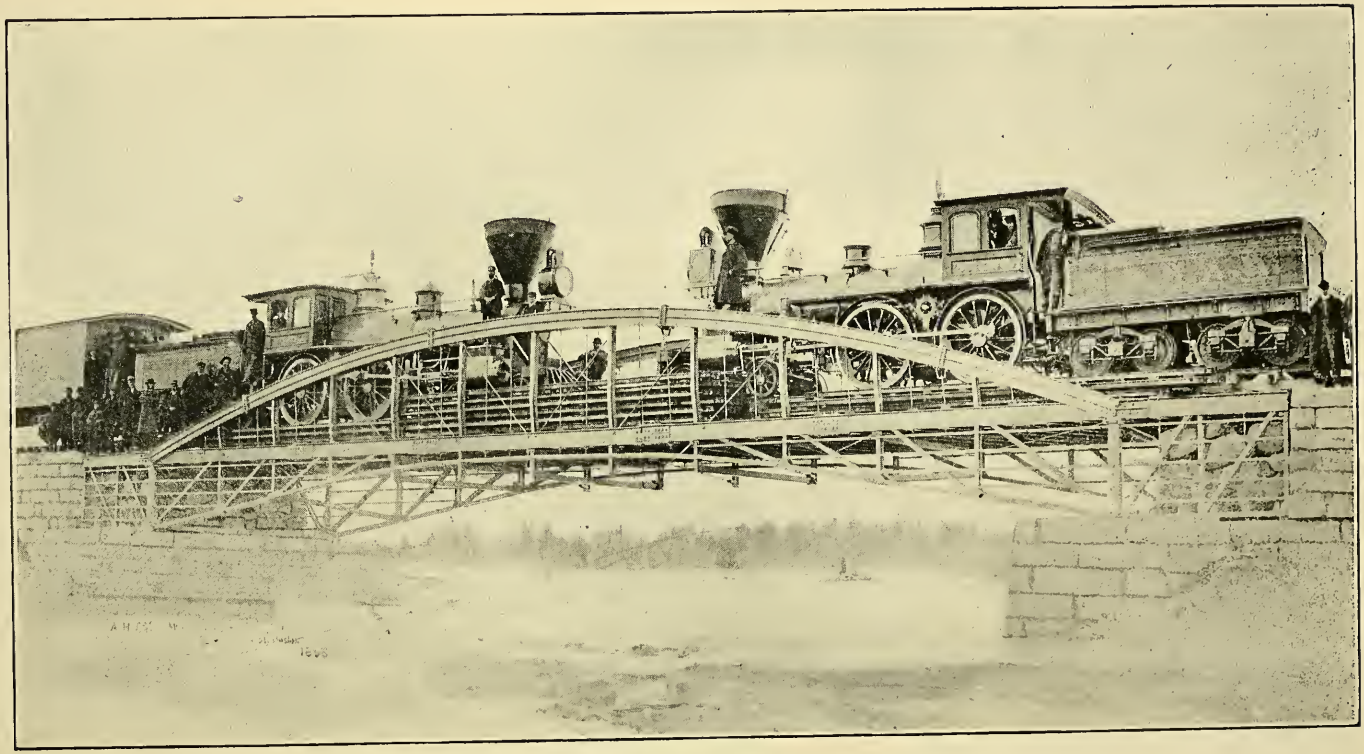


FIG. 2. BRIDGE OVER OLAMON RIVER, MAINE.

carpenter and wooden bridge builder named Cottrell. He had built many wooden Howe-truss and lattice bridges, and became possessed with the idea of avoiding false work in swift rivers and deep chasms by building from the shore outward through space to the opposite abutment or first pier, and so on, anchoring the shore end during projection by weighting or guying.

I am told that Cottrell convinced a bridge company at St. John, N. B., that he could span the 500-foot gap at the rapids there in that way, and actually projected his latticed trusses into space 100 feet; but, becoming frightened by sure evidences of coming catastrophe, he suddenly left town for other parts. Later he succeeded in erecting a wooden lattice bridge in this way in Maryland, with the help of an engineer, who made provision for increased strength in members where the strains were temporarily reversed during the projection.

Cottrell was clever at figures without a deep knowledge of mathematics, and published a pamphlet containing some of his discoveries, one of which was that Archimedes was wrong in giving the approximate value of π as 3 1-7 times the diameter. The humble author of the pamphlet found it to be $3\frac{1}{8}$ times. One proof adduced was that, with this value, many problems could be solved without fractions, the circles squared, etc. To test his new ratio he had encircled an old millstone with a thin carpenter's shaving, and found the circumference to be exactly $3\frac{1}{8}$ times the diameter.

Later he saw the advantage of projecting a half span from each shore, and conceived and patented the design shown in the photograph.

He came to Boston about 1867 or 1868, and was employed at the Chickering pianoforte factory, where he made the acquaintance of a fellow-workman, Levi Liscom, who had built wooden bridges in New Hampshire and Vermont. He convinced Liscom, and through him several men of financial influence, that his patent solid lever projected without false work from opposite shores was the coming bridge. A company was formed, and the Oliver street gap gave the opportunity for a conspicuous advertisement. The contract price was $1000.

It will be noticed that the arch springs from a point far back from the fulcrum point of the levers. The reason for this was a brilliant discovery of Cottrell's, viz:, that the thrust of the arch could be utilized for balance power to help support the levers. The arch was an afterthought, and was added to prevent the sagging of the slim center ends of the levers. The theory advanced later was that the levers sustained the dead load and the arches the live

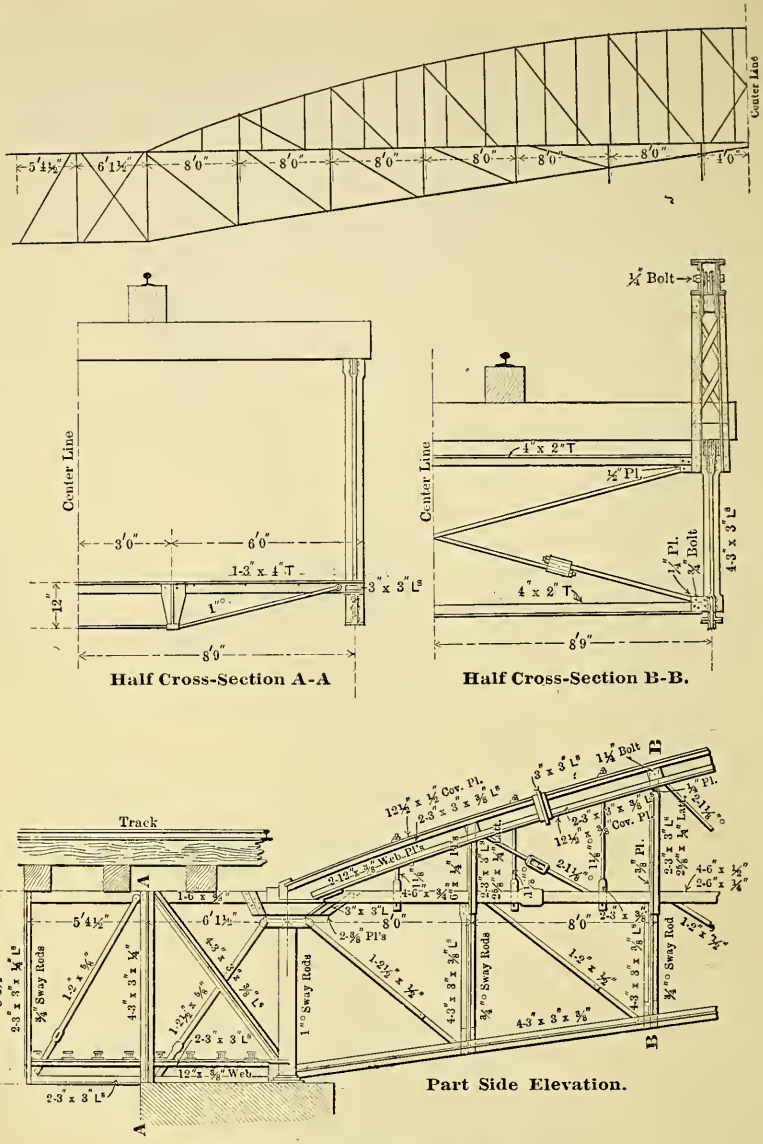


FIG. 3. MAGUAGADAVIC BRIDGE.

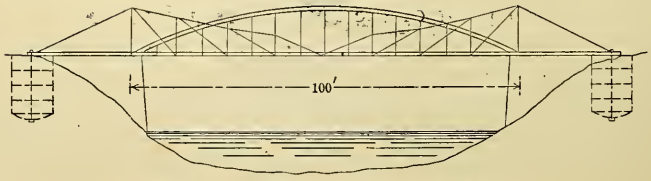


FIG. 4. OROMOCTO, SOUTH BRANCH.

load. In practice, owing to debris working under the shore ends of the levers, they failed to act, and the arches carried both live and dead loads.

This bridge afterwards fell from the crumbling of the clay and gravel banks under the fulcrums.

The one important feature of this bridge worth mentioning and recording is the use of the cantilever principle to erect without false work, the first case of the kind, as far as I can learn, in this country.

Mr. Theodore Cooper, in an article on bridges published in Vol. 21, page 1, of the "Transactions of the American Society of Civil Engineers," says that the first use of cantilevers in bridge erection was by Capt. James B. Eads, in 1874, who used balanced cantilevers 250 feet long in erecting the 500-foot steel arches of the St. Louis Bridge. According to the *Scientific American* this occurred one year earlier, in 1873. Mr. Cooper further says that the first cantilever bridge built in this country was over the Kentucky River, in 1876-77, by C. Shaler Smith; the Niagara cantilever in 1883, the Frazer River cantilever in 1885, both designed by C. C. Schneider, and the St. John, N. B., cantilever in 1885. Later instances are well known.

In a book, published in 1811 by Thomas Pope, entitled "A Treatise on Bridge Architecture," the author describes at length his ideas for a flying pendant lever bridge with diagrams. It does not appear that Mr. Pope's scheme was ever carried out in practice.

The agents of the Solid Lever Bridge Company started out to introduce the new bridge, but were met with the demand from the railroads for iron instead of wood. One wooden highway bridge was built near Worcester. They declared the principle just as well adapted to iron, and made contracts for iron bridges at about the price of wooden ones; among them five bridges on the European and North American Railroad between Bangor, Me., and St. John, N. B., with spans varying from 50 to 154 feet. As a substitute for the laminated deal construction of the levers, it was proposed to use channel iron set on edge, riveting the flanges together, building up the solid lever by projecting the channels successively, as before with the plank. The backs of the channels were to be crossed by vertical tee-bar stiffeners. A tin model of a 25-foot span was made and set up in the corridor of the Merchant's Exchange building, and the heavy men of Boston walked across it and pronounced it remarkably stiff and strong.

Hundreds of tons of beams, channels, angles and tees of various sizes were bought in England and Europe before any working

drawings were made. Crude drawings for a 50-foot span railroad bridge over Costigan Brook, near Bangor, Me., were the first made; and negotiations for the shop-work were under way when it became evident, to the few who had money at stake in the enterprise, that an engineer was necessary; and in 1868 Mr. C. H. Parker (later a member of this Society) was called in. His task was a peculiar and difficult one, viz., to make, largely from the great mass of material already bought, safe bridges for railroad traffic with the strains properly provided for, while limited, of course, to the patented arched cantilever type which the company was formed to build.

Mr. Parker at once condemned the *solid* lever and substituted the skeleton form with members in the line of the strains, placed the end bearings of the arches directly over the fulcrum points of the levers, provided separate chords for lever and arch in the longer spans, with expansion joints in levers at the span center and roller-end bearings for the arch. The channels on hand made lever chords and excellent arches; the I-beams were used for posts and struts, pin-connected flat bars for the chord of the arch in the longer spans and plates and angles for various other members. The designs embraced some very unique details. The results gave strong and safe bridges for the loads then in use, at a cost, however, greatly in excess of the contract price, but fulfilling in honorable fashion a number of very foolish contracts.

These bridges (about eight in number) were all built in 1868 and 1869. They were, where necessary or desirable, erected without false work, and all did good service for many years.

The Costigan Brook bridge, 50-foot span, near Bangor, Me., on the Maine Central Railroad, was in use fifteen years, or until 1883. This was the first one of the lot erected, and the only one of the iron bridges having the solid levers.

The Olamon bridge, in Maine, Fig. 2, on the same railroad line, 75-foot span, was in use eighteen years, or until 1886, at which time Mr. J. P. Snow made a report on it, suggesting changes which might possibly prolong its life, but it was decided to replace it by a new bridge.

The Maguagadavic bridge, Fig. 3, 104-foot span, was on the connecting railroad line in New Brunswick. How long it remained in use I have not learned. Mr. Job Abbott, member of the American Society of Civil Engineers, during a trip in New Brunswick, saw this strange bridge, took measurements and had drawings made, from which an illustrated article was prepared and published in the *Engineering Record* of July 27, 1901. Mr. Abbott supposed



FIG. 5. BRIDGE OVER ASSABET RIVER, WEST CONCORD, MASS.

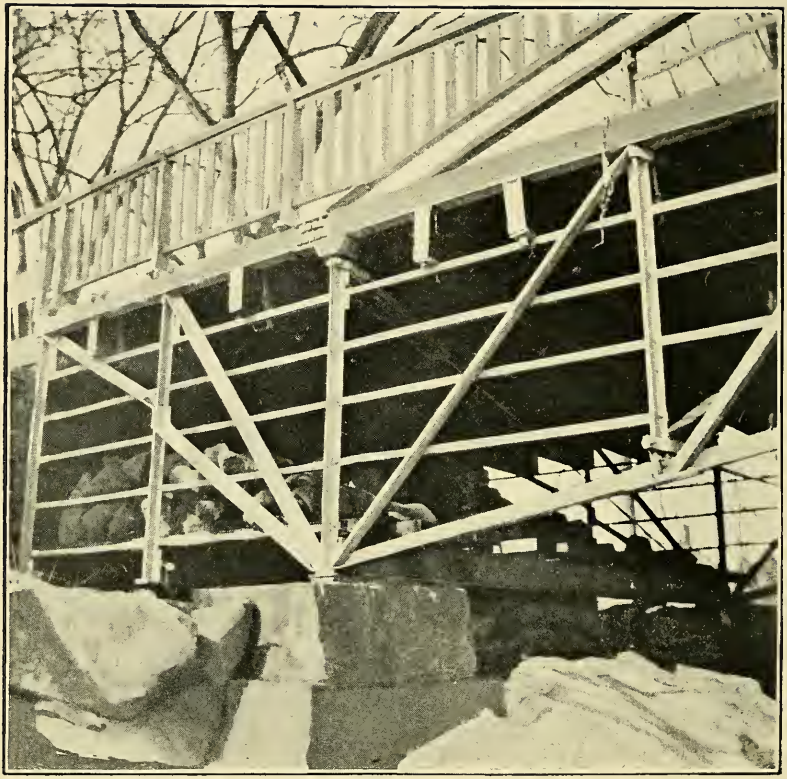


Fig. 6. Shore End. Bridge over Assabet River.



Fig. 7. Bridge at Fitchburg, Mass.

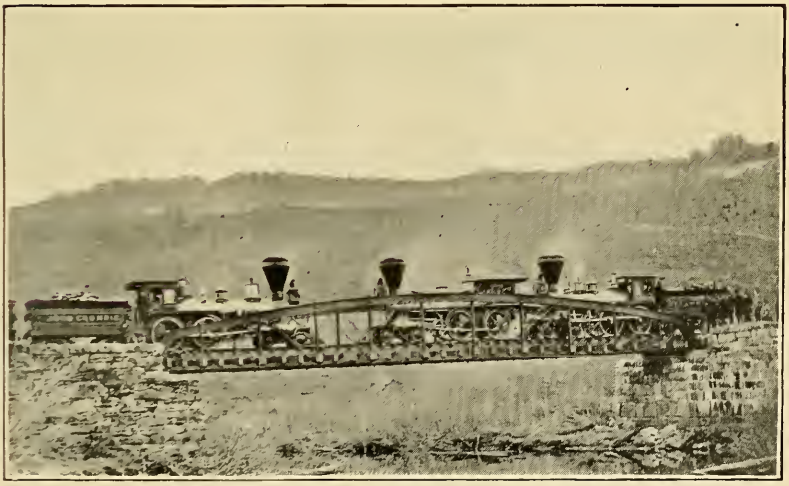


Fig. 8. Bridge at North Woodstock, Vt.

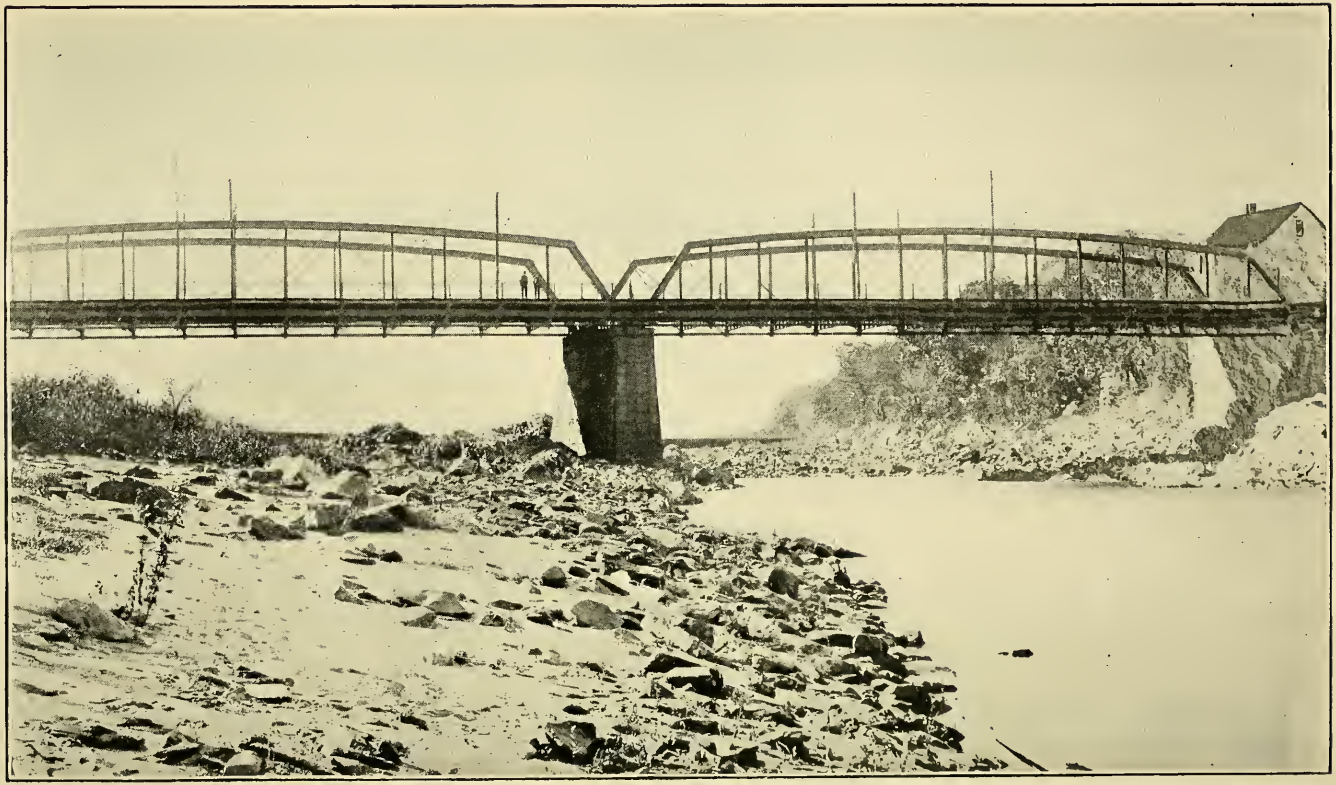


FIG. 9. BRIDGE OVER MERRIMAC RIVER, LOWELL, MASS.

that this and the two following bridges, all in New Brunswick, were made in England.

The bridge over the north branch of the Oromocto River, near Frederickton, N. B., 154-foot span, was the best sample of the lot, having separate chords for lever and arch and provision for expansion. It was in use till about 1895; and it is my impression that it was then swept away by a freshet and log jam.

The bridge over the south branch of the same river, Fig. 4, 100-foot span, was unlike all the others in having both levers and arches above the roadway. It had separate chords for arch and lever and provision for expansion. I have no record of the life of this bridge.

A highway bridge, Figs. 5 and 6, was erected at West Concord, Mass., over the Assabet River in 1869, and was in use as late as 1899, when it was replaced by a concrete arch designed by Mr. J. R. Worcester, who can tell the condition of the old bridge after thirty years' service.

Mr. Parker was a firm believer in the cantilever principle; and, at the time when John A. Roebling was urging the suspension bridge for railroads, said that the cantilever bridge would supersede the suspension bridge for railroad traffic, except for the very longest spans. He realized the absurdity of combining the two systems (lever and arch) in one bridge and of using the lever for anything but long spans. He made the arch strong enough to carry all loads, live and dead, and placed little reliance on the lever. He made study plans for a cantilever bridge across the chasm at St. John, N. B., over the rapids, where a similar bridge has since been erected; and, in 1876, when the cantilever type was proposed for a railroad bridge across the East River and lower end of Blackwell's Island, he was pronounced in its favor.

The Solid Lever Bridge Company was succeeded, in 1869-70, by the National Bridge and Iron Works, with Mr. Parker as chief engineer, now free to choose the type of bridge he thought best in each case. Between 1869 and 1876 the new company built many truss bridges and iron buildings, including three bridges across the Merrimac River, the Lowell Railroad and Providence Railroad train sheds, the Boston post-office roof and many highway bridges throughout New England. To one form of truss Mr. Parker felt justified in giving his name and secured a patent, viz., a truss with inclined end posts, curved top chord and vertical interior posts, otherwise a Pratt truss. Examples of this truss are shown in Figs. 7, 8 and 9. The advantages claimed were the shorter posts for the increasing strains toward the ends, more equal strains

throughout the chords, retaining the good points of both the bowstring girder and the rectangular truss.

From 1871 to 1874 Mr. D. H. Andrews was employed as assistant engineer, and gave much thought to the working out of the train sheds for the Lowell and the Providence railroads and of other structures.

In 1876 the company failed, and in the same year the Boston Bridge Works was formed by Mr. Andrews, who purchased a considerable portion of the plant of the old company and retained many of its employes, a number of whom are still with the Boston Bridge Works, occupying responsible positions.

From 1876 to 1884 Mr. Parker was in Pittsburg, Pa., as general manager of the Fort Pitt Bridge and Boiler Works. In 1877 this company built, for Jas. B. Eads, the iron dredge boat *G. W. R. Bailey* for use at the Jetties below New Orleans.

From 1884 to his decease in 1898 Mr. Parker was in Boston, engaged in the manufacture of portable hoisting engines and mining machinery, ten years with Edward Kendall & Sons and four years in business for himself. His record in the bridge line was creditable. His bridges were all made for specified loads, and careful strain sheets were made in each case. Many of his bridges are still in use as originally built; some have been outgrown and replaced, some have been strengthened for heavier loads and are still in use, but none ever failed, and this is more than can be said of a number of bridges built during the same period by others.

DISCUSSION.

Mr. Joseph R. Worcester.—I am very glad of this opportunity to testify to the remarkable work in the bridge line which was done by Mr. Chas. H. Parker, with the assistance of his brother, the speaker of the evening, during the early seventies and even earlier.

Sufficient credit has never been given Mr. Parker for the advance in the science of iron bridge building which was due to his persistent study and the painstaking care with which he worked up his designs.

It has been my fortune to examine a number of bridges built by Mr. Parker, among which are those across the Merrimac at Haverhill and at Lowell, at Taunton, at Pawtucket, R. I., at Northampton, at Lawrence, as well as the cantilever arch at Westvale Village, Concord, Mass., and in each case I have been greatly impressed by the skill and faithfulness with which the work was executed.

A few points of weakness appear in each, according to modern

methods of figuring, but so well was the work done, that the weakness rarely shows itself after many years of use. For instance, we find in many cases floor beams in the form of an open Pratt truss, the posts and chords composed of two angles, and the diagonals of a single flat bar, with the connection at the intersection often made by means of a single ¾-inch rivet. This rivet, under the heavy concentrated loads of to-day, will sometimes have a phenomenally high strain per square inch in bearing, but I have never found one seriously weakened and rarely one loose. This is apparently a case where Mr. Parker knew more about what a rivet was good for than we do to-day.

Another point in these bridges which figures high but, so far as I am aware, never gives out, is the bottom chord pin. The joints in the chords are usually outside the panel points, the flat bars meeting end to end and having splice plates on each side of each bar connected by single pins or, rather, bolts, which seem wonderfully small, according to our methods of figuring, but they are all right so far as any evidence of distress is an indication.

The principal trouble with the old bridge at Westvale was that the arches were insufficiently braced transversely. The floor beams in this case were wooden, and, of course, it was impossible to attach the trusses to a wooden floor in a manner wholly permanent and satisfactory. The consequence was that the arches became badly bent laterally. No restriction was ever placed upon travel over the bridge, and nobody ever suspected its weakness, apparently, until it was examined with a view to the possibility of carrying an electric road over it.

In general, it may be said that Mr. Parker's trusses were of ample strength, and in appearance much more artistic and graceful than anything built up to their time and than much which has been built since. The weak spots, if any, can generally be found in his floor systems, which were built for far lighter concentrations than are now used in the streets.

The most remarkable work will be found in the details which, while wholly new and original at the time, have now come into general use in many cases, and where they have been superseded it has often been on account of inventions, such as the manufacture of upset eyebar heads, which allow different types of construction from what was then possible. In this particular part of the work the speaker of the evening found his field, and he is entitled to his full share of the credit.

Mr. J. Parker Snow (by letter).—I wish to indorse and supplement what Mr. Worcester has said as to the credit due to the

author of the paper for his part in the development of iron bridge building in its early stages in New England. His rare grasp of structural detail has, in my opinion, left a mark on our practice of bridge building that will be carried far into the future.

The paper is a valuable bit of history, and an interesting addition to it would be a description of the progress of the author's personal practice in planning the shop-work for building bridges when nothing but the strain sheet was furnished him from which to work. That is, in clothing a skeleton diagram with sufficient metal to carry the prescribed strains and in arranging proper connections to secure the members together. This was the author's peculiar field. It was really engineering, but it went by the name of pattern making. A full history of this "pattern making" would, I feel sure, show the origin of some of our best practice to-day.

The instances of startlingly high strains in rivets and pins mentioned by Mr. Worcester is, as he intimates, rather a reflection on our modern practice than on the old designs. Our experience shows us that some of our theories of modern designing are wrong, but we do not know enough yet to correct our theories, and it will not do now, as it would thirty-five years ago, to design by guess.

The author is in error as to my connection with the Olamon bridge. It was the bridge over the south branch of the Oromocto River in New Brunswick that I investigated. This, as the paper states, had the arch and levers above the floor. Mr. D. H. Andrews, proprietor of the Boston Bridge Works, examined this bridge in the winter of 1882-83, and from drawings which he procured I made calculations from which to investigate its strength. I think the arch and lever were originally so connected that sufficient horizontal play was allowed for expansion, but, as these connections gave trouble, for the reason explained farther on, they were in course of time riveted up solidly, and then the structure was firmly fixed at the ends by the lever counterweights and made continuous at the center by the arch, hence there was no chance for contraction or expansion except by tearing these connections apart.

According to my investigation the inherent defect of the structure was the connection of the two systems at every panel point. The deflection curve of an arch is approximately a parabola, everywhere convex downward. The deflection curve of a pair of levers has a cusp at the center and is everywhere concave downward. If these two systems are constrained to deflect to the same curve by being riveted at each panel point, the connections will be severely tried at certain points.

The arch of the bridge in question was a very much more

rugged member than the levers, and hence the latter suffered. The rupture of members near the extremities of the levers, and the constant tearing apart of the connections between the arch and levers, caused anxiety as to the strength of the bridge, and led to the call for its examination by Mr. Andrews. My computations led me to think that, if the levers were cut free from the arches except at the center, the bridge would be amply sufficient under the loads in use at that time.

Mr. David A. Hartwell.—I am not certain that it is quite the thing for a new member to make remarks, but I have been much interested in Mr. Parker's paper. Being from Fitchburg, I was especially interested in the Parker patent bridge and the historical matter which led up to its inception, as we have three of those bridges in use at the present time. The Rollstone street bridge has a span of 108 feet, and was erected in 1870; the Kimball street bridge has a span of 90 feet, and was erected in 1870; and the Circle street bridge has a span of 73 feet, and was erected in 1871. The Circle street bridge has no sidewalk, but the other two have walks on each side outside the trusses. These bridges are all within the built-up portion of the city, and are subjected to a constant and at times a heavy traffic of the teams from the granite quarries. All three bridges are in good condition, and I see no reason why, after over thirty years of continuous service, they are not good for years to come. We have a 20-ton road roller, but I have never allowed the street department to drive the roller over any of these bridges, as I have doubts as to the ability of the structures to sustain such a concentrated load.

THE BURNING OF PULVERIZED COAL.

By C. O. Bartlett.

[Read before the Civil Engineers' Club of Cleveland, May 12, 1903.*]

To burn coal in a powdered form successfully, three things are necessary, (1) uniformity of moisture, (2) uniformity in size of grain, and (3) the amount of air required for perfect combustion. In my judgment, it is impossible to get perfect combustion by feeding coal in different states of moisture.

First. Coal varies in moisture from 4 per cent. to 15 per cent. During the summer season, especially, ordinary bituminous coal frequently has not more than 4 per cent. moisture, while during the winter and spring or during the rainy season, and especially when the coal is saturated with water and then frozen, the same kind of coal will contain as high as 15 per cent. moisture, and much of this moisture in the form of ice. We cannot expect to get the same results by burning coal with this amount of moisture as can be had by burning the same kind of coal with 4 per cent. moisture. Therefore, it is absolutely necessary to have the coal uniform as to moisture.

Second. It is impossible to get the best results by burning large pieces of coal together with the dust of the coal. The coal must be reduced to grains of equal size. In other words, it must be powdered or pulverized. It should be 80 mesh fine.

Third. The right amount of air or oxygen is necessary for the perfect combustion of any kind of coal. I believe it is generally conceded that about 140 cubic feet of air are required to burn a pound of coal. The admission of air cannot be successfully controlled by natural draught. Forced draught, either of compressed air or by a fan or blower, must be used. The blower is by far the cheaper.

If the three requisites named are secured, perfect combustion can be had, and perfect combustion means:

(a) No black smoke.

(b) No cinders, and very little ashes.

(c) A saving of practically 40 per cent. in the amount of coal used.

A test was made on a 60 x 18-inch horizontal tubular boiler, of about 125 horse power, and the tests were made as follows: First we would run a day on powdered coal, the next day on slack

*Manuscript received May 20, 1903.—Secretary, Ass'n of Eng. Socs.

coal and the next day on run-of-mine. We afterwards made a test of longer duration, running 88 hours on powdered coal and 48 hours on the same kind of coal without drying and pulverizing and by hand firing, and the gross saving was found to be about 40 per cent. in the amount of coal used. Six per cent. of moisture was taken out of the coal. When burning the powdered coal, the amount of ash did not exceed 3 per cent., while in the ordinary way of firing it was a little over 19 per cent.

In making this test there was a slight variation in the power used, but not enough to make any difference in the result. Every pound of coal was carefully weighed, so that no mistake could occur.

It is readily understood that from this 40 per cent. in saving must be taken the cost of crushing (when lump coal is used), drying, pulverizing and feeding; and these different items we will now consider:

I will take it for granted that slack coal is used, that it is just as cheap as run-of-mine coal, if not cheaper, although, if this system should come into general use, there would of course be no difference in the price, for the reason that the coal miners would simply sell their coal in the form of slack; that is, they would crush it at the mines.

The first matter to consider is the cost of drying. Our firm has built dryers for many years, and I am quite familiar with this part of the business. We are always willing to guarantee to evaporate 8 pounds of water or moisture by the use of 1 pound of fuel. For the drying of coal we recommend the use of the rotary cylinder dryer, using direct heat, and the products of combustion passing on the outside of the cylinder only. In some few cases the products of combustion are first allowed to pass on the outside of the dryer, then to pass through the coal, and when this is done it is safe to estimate on a basis of 10 pounds of moisture evaporated by 1 pound of fuel.

But the passing of the products of combustion through the dried coal is, to say the least, a little risky, and no risk under any circumstances should be taken in the handling of coal dust, although we are doing this in some cases. I had the pleasure of talking with Mr. Wilson, of the Schwartskopf Coal Dust Firing Syndicate, of Haydock, England, who was sent here by his company to investigate the merits of our dryer, and he said that in England they would not, under any circumstances, think of passing the products of combustion through the coal while it was being dried. This company has experimented very largely in the burning of pow-

dered coal; in fact, they claim to have spent sixty thousand dollars in experimenting and in putting their system on the market. They are now introducing it in the United States. The Illinois Central Railroad passenger depot, Chicago, has been using one of that company's dryers. Therefore, taking everything into consideration, I think it is safe to estimate the cost of drying the coal on a basis of 8 pounds of evaporation to 1 pound of fuel. Estimating on a basis of $2 per ton for coal and taking the loss in moisture at 5 per cent., the cost of drying and the loss in moisture will be less than 12 cents per ton. This estimate is based on drying not less than 40 tons a day. If the amount to be dried is less, the price will be correspondingly higher, and if the amount be 100 tons a day, the price will be a little, but not very much, lower.

Second. The cost of pulverizing, with one good mill, using 25 horse power, 4 tons of coal can be pulverized in an hour. The cost will be somewhat reduced by improved machines which are fast coming into use. At the present time there are three systems:

The French Buhr or Emery Wheel system.

The Huntington or Centrifugal type.

The ball or tube mill system.

To these I might add the Kent mill, which is now being put on the market, and in which the pressure of the rolls against the casing is obtained by means of screw pressure, which adds to the capacity and at the same time admits of great reduction in speed, adding greatly to the life of the mill. There is also at present on the market a new invention by a Cleveland man, and, I think, a member of this Club, Mr. Fleming, which, in my judgment, will still further reduce the cost of pulverizing the coal. At present it is safe to estimate on a cost of ten cents per ton for pulverizing.

Third. The cost of elevators, conveyors, bins, cost of running blower or feeder, interest on investment and wear and tear should not amount to more than 10 cents per ton, and probably not more than 5 cents per ton, making the total cost of drying, shrinkage, pulverizing, feeding and cost of driving the machinery, interest on investment, etc., in quantities of 40 tons a day, about 32 cents per ton.

This shows, on 40 tons of coal a day, coal costing $2 a ton, a net saving of a little less than $20 a day, or 50 cents per ton.

Another important factor, which I have not considered, is the doing away with the fireman, as in the use of this system no fireman is required. The fireman's wages are therefore saved. Also, there is not more than one-third as many ashes, and there are no cinders at all.

I have shown the credit side of this matter, and I will now consider the other side, or the obstacles to be overcome in successfully burning pulverized coal.

To burn pulverized coal economically it must be burned in fairly large quantities; in other words, I do not think it would pay to put in a drying and pulverizing outfit unless the amount of coal used is at least 10 tons per day. In large cities this difficulty can be obviated by having a central drying and grinding plant and selling the pulverized coal to small consumers. In this case it would be necessary simply to put in a feeder, for feeding the coal in a powdered form, and a tank for holding it.

The next obstacle, and one which I consider of very great importance, is the danger arising from storing large quantities of powdered coal. That there is danger in doing this I have no doubt.

From the best information that I have been able to obtain I do not think it is practical to store large quantities of pulverized coal for any length of time, and this means that it would not be practical to dry and pulverize the coal at the mines and ship it in this form. Neither would it be practical, in my judgment, for a boat, say the *Northland* or the *Northwest,* which now use about 500 tons at one trip, to put in that amount of powdered coal at Buffalo or Cleveland, with the intention of storing it for the round trip. The only way would be to store the dried coal and to pulverize and feed it on board the boat as they need it. In any case, the dust should be stored in iron receptacles.

The next question, and quite a serious one, is the construction of the arch. In our experiment we used the Rowe system, which consists in blowing the pulverized coal, by means of an ordinary fan or blower, up against an arch over the fire. In other words, burning it in suspension. The arch wall becomes very hot and immediately ignites the coal, and when the proper amount of air is used the combustion is perfect. We find that a 2-ounce pressure is best for this purpose. It will be readily understood that, in order to withstand this excessive heat, the best kind of arch wall is necessary, and that specially constructed brick should be used. While this is really quite a serious question, I do not doubt that it will be satisfactorily answered. Mr. Fred. Siegheim, of Germany, has an invention for covering the arch wall, by which it can be made to withstand a tremendous heat, up to 3000 degrees or more, without injury, and to last for a long time; in fact, until the draught of air has worn away this material. As near as I can ascertain, this mixture is composed largely of the dust of carborundum, which is now being manufactured in large quantities

at Niagara Falls. In taking the matter up with this company, I find that Mr. Siegheim has contracted for the exclusive output of this dust for five years. I consider this a very important invention and well worthy the most careful consideration of the engineers of the United States. It seems a little humiliating that the Germans should get ahead of us, but such seems to be the case.

As near as can be estimated, the cost of an outfit for, say, 40 tons per day of 10 hours, will be as follows, using slack coal:

Dryer, estimated cost	$1,500.00
Pulverizer, estimated cost	2,500.00
Feeders, estimated cost	1,000.00
Conveyors, elevators, bins, etc., necessary handling of machinery	2,000.00
Total	$7,000.00

Of course, this cost will vary considerably according to circumstances.

Among other important advantages of the use of pulverized fuel is the absolute elimination of smoke, and this is one that ought to be considered by every manufacturer, especially in the cities. When our health officer says, as he has said on several occasions, that the death rate is considerably higher in the smoky sections of the city than elsewhere, and especially in pulmonary troubles, it ought to be sufficient to induce us all to do our best to do away with the smoke nuisance. Most of us have to get our bread and butter in the central part of this city. To live in a cloud of smoke must necessarily weaken us physically and shorten our lives. Therefore, every manufacturer should do his utmost in every way to eliminate this smoke nuisance.

INDEXED.

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

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ACTION OF SEA WORMS ON FOUNDATIONS IN BOSTON HARBOR.

BY F. W. HODGDON, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Remarks at meeting of that Society, February 18, 1903.*]

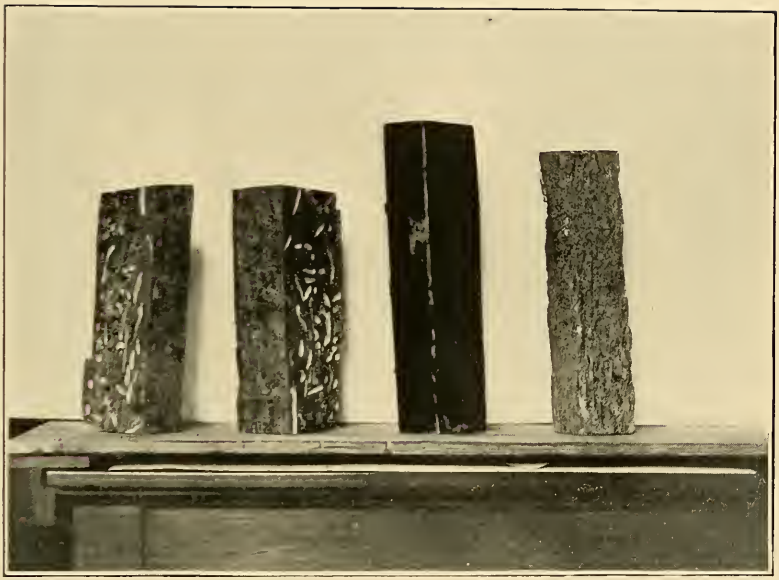
THE trouble from worms in Boston harbor is due principally to the *limnoria terebrans,* a small worm which eats timber from the outside. In attacking piles it eats on all sides of it, the principal activity being a foot or two below low water mark, and it eats in very much as a beaver cuts off a tree, eating away the wood until only a small section not much larger than a pencil remains at the center, which is generally broken off by the waves or other forces. The way in which it eats into plank is shown by the sample marked "a" (Fig. 1) which I have here. This was taken from a bulkhead built through the center of a wharf on the Commonwealth Flats at South Boston, built for the Metropolitan Coal Company, and shows the results of the work of the worms for two seasons. This other sample marked "b" is from a plank taken from the same bulkhead at about the same elevation, but this second one was treated by painting it over with carbolineum avenarius, a patented wood-preserving preparation. At the time the bulkhead was built it was desired to get some information as to the value of the preservative, and a portion of the spruce planking and timbering was coated with it, being applied hot with a brush after the planks had been dried to a certain extent. As you can see, the coating has practically preserved the plank from the attack of the worms, only a few holes having been bored into it, and these in spots evidently where the coating had been worn off in the handling of the timber.

*Manuscript received August 13, 1903.—Secretary, Ass'n of Eng. Socs.

These worms are very active in the clear salt water in the outer harbor, and I am told that where the water is clear, as it is in the outer harbor, they will eat off a spruce pile in about five years. Around the city wharves, where the water gets foul from sewage and other refuse thrown into it, the worm cannot live, and further up in the rivers, where the inflow of fresh water is so great as to materially reduce the proportion of salt in the water, the worm is not found.

Another worm, known as the *teredo navalis,* or ship worm, has given us very little trouble in Boston, although it is found all along the Atlantic coast. South of Cape Cod it is very active, and at Norfolk I am told that it will eat off an oak pile in one year. This worm acts in an entirely different manner from the *limnoria,* as is shown by samples "c" and "d" (Fig. 1). It enters the timber through a very small hole, and after it is inside, grows and bores out a chamber about one-quarter of an inch in diameter, winding through the timber in an irregular manner, but never boring out through the face, but coming so close to the face of the timber that holes are very easily forced through it.

The only real case of this worm in Boston harbor that I know of occurred a few years ago in some new scows owned by one of the dredging companies. These scows were built during the winter at Bath, Me., of timber brought from Georgia. In the spring they were put in service first in the upper harbor of Boston, and after being in use a short time there were sent down to the mouth of the harbor where the main channel was being dredged. After being in use for a few months they began to leak very badly, and upon examination it was found that their bottoms were honeycombed by the *teredo.* Upon an examination of some old scows built of spruce timber, which had been lying alongside of the new ones, it was found that they were also eaten to a considerable extent. The scows were withdrawn from service and replanked, and after being caulked, sheathing paper was placed over the bottom, and outside of this 1-inch boards were spiked to the sides and bottom of the scows up to the light water mark. After this no further trouble was had with them and no other scows appear to have been affected. One peculiarity of this worm is that it will not bore from one plank into another, no matter how tight the joint may be, but will always stay in the timber which it has first entered. Relying on this fact, timber has often been protected by nailing inch boards on the outside of it, the worms entering the inch boards, but not crossing the joint into the main timber.



d c b a

FIG. 1.

I have heard some statements that the worms had been found in and around Boston at other points, but it has always been reported that they were dead. The *teredo* attacks hard woods, such as oak and the like, often more readily than the soft woods. Very soft wood like the palmetto it will not attack at all, while the *limnoria* is much more destructive to the soft woods than to the hard. While it will readily eat the spruce piles, I have never seen an oak pile which was eaten sufficiently to injure the pile, and I have examined some piles which have been in place over fifty years.

To protect our sea-wall foundations from these worms we have to be very sure that the piles are completely covered by the riprap or filling around them so that the worms cannot get at them. At the pier built by the New England Railroad Company at South Boston, the material surrounding the heads of the foundation piles at about low water mark was washed away at a few places and I had the heads of the piles examined and found that the worms had got in and eaten the heads of the piles to a considerable extent. The railroad company had the filling replaced, and that undoubtedly stopped the further action of the worms.

In a wall which I designed and built about two years ago, in order to be sure that the heads of the piles were fully protected, the piles, for a distance of about 3 feet below low water mark, were surrounded by concrete, which came up over the heads of the piles and was leveled off to receive the stone sea-wall. In front of this the riprap was placed. The ordinary method of capping the piles in these sea-wall foundations is to cover them with a grillage of timber or plank on which to start the stone masonry. In order to get the foundations as low as possible the work has to be done at times of extreme low water, and as these occur only for a short time each month, the work is often very much delayed. By using concrete it can be placed when the tide is not so low and the work is facilitated very much, and also it protects the heads of the piles much more thoroughly. Another advantage is that it is very difficult to be sure that the riprap around the piles is filled in solid under the timber grillage. In the case of the concrete it has to be supported on this riprap until it sets, and therefore it makes a solid connection with the riprap.

DISCUSSION.

Q. Do these worms work in summer or in winter?

Mr. Hodgdon.—Practically only in summer and in warm weather. The *teredo* is very active on the south shore of Massachusetts; it acts only in the summer months. The work of the

teredo is all done below the level of low tides. At about 1 foot below low water you begin to find them.

MR. FERNALD.—How far North, Mr. Hodgdon, does the *teredo* work?

MR. HODGDON.—It apparently does not come into Massachusetts Bay. They have them at Halifax and Nova Scotia. It is a smaller worm than in the South; it may be that cold weather keeps them from growing as large here as in the South.

Those in the dredging scows were quite large. I have seen some about the same size that came from Southern ports.

Q. Will the *teredo* attack lumber that has been treated by kyanizing or other process?

MR. HODGDON.—I don't know about the kyanizing, but at the Norfolk navy yard they have a timber dry dock and the outer platform and gate was built of creosoted timber and held the worms off for a long time. The worm in that vicinity will destroy an oak pile in one season, but this creosoted work held, I think, ten or twelve years, then they found the worms had got into it and they had to renew it. Creosote cannot be forced into long-leaf pine, as it is too solid. They have to use the softer, spongy short-leaf pine, in order to get sufficient oil into it to preserve it.

Q. I would like to ask Mr. Hodgdon in that case of the old Boston Electric Light Company's station on Summer street, if the appearance of the pile heads was exactly identical with that sample of the worm of the *limnoria?* I think that was at grade 7½.

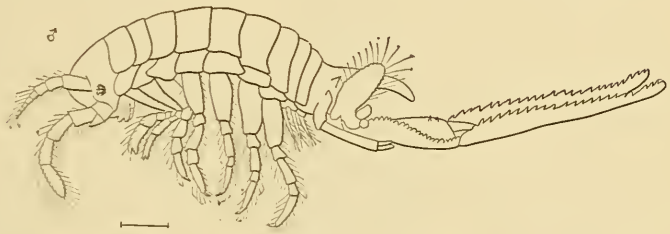
MR. HODGDON.—The planks that are in the wharf that this sample was taken from were in a spruce bulkhead that was built through the middle of the wharf to prevent the waves from driving through. The upper portion of the plank was not attacked at all, and almost invariably I found the worms eating just above the mud and up to just below low water. That is where they get in their work; it is where they are covered up by the water all the time.

MR. HENRY MANLEY.—In the year 1888 a careful examination of the pile bridges in the city of Boston was made with special reference to the danger from marine worms or timber destroyers. It came about through an accident on the bridge of the Fitchburg Railroad over the Charles River, caused by the giving way of overloaded oak piles. One of the broken piles showed a single hole about as large as a pipestem, which may or may not have been bored by the *teredo*. The fact that this hole was found was exploited in the papers, and an examination of the bridges belonging to the city was ordered by the city government. A special report was made in October, 1888, and in the regular annual report of the

city engineer for the same year some of the results of the examination were given in more detail. The report quotes from "The Fisheries and Fishery Industries of the United States," by George Brown Goode, 1884, a publication of the United States Fish Commission, and as it is the best concise description of the *limnoria* with which I am acquainted, it is here reproduced.

THE GRIBBLE OR BORING LIMNORIA—*Limnoria Lignorum, White.*

"The little crustacean pest, which measures less than one-fifth of an inch in length, is a very common inhabitant of our Atlantic coast from the Gulf of St. Lawrence to Florida, and also occurs abundantly on the coast of Great Britain and of other parts of Europe. In spite of its small size, it is very destructive to all kinds of submarine woodwork, which it rapidly eats away. Its body,

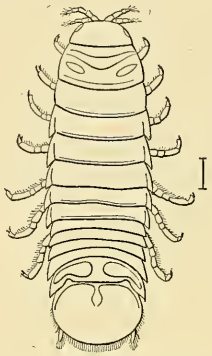


CHELURA TEREBRANS; MALE; LATERAL VIEW. ENLARGED ABOUT TWELVE DIAMETERS.

which is subcylindrical in shape, consists of fourteen segments, the anterior one being the head; the two ends are rounded and the sides are nearly straight and parallel to one another. The first seven segments, not including the head, bear each a pair of short legs. It makes its burrow by means of stout mandibles or jaws. In color it is grayish, the upper surface of the body being covered with minute hairs, to which more or less dirt usually adheres.

"The gribble generally lives above and just below low water mark, but has been found at times, though very rarely, as low down as 7 to 10 fathoms. It gnaws burrows into all sorts of sunken or floating wood near the shore, and lumber or driftwood left for some time on muddy shores is pretty certain to be attacked by it. The burrows are made to the depth of about half an inch, and when they become numerous enough to reduce the superficial layer of wood to a mere honeycomb, it scales off, leaving a fresh surface, which is at once attacked. Much damage is done by this little creature to the piles of wharves and other submarine woodwork all along our Atlantic coast, and numerous methods of stopping its ravages have been devised. It has been observed attacking the

gutta-percha of submarine telegraph cables. Professor Verrill describes its habits and the damage done on the American coast as follows: 'It has the habit of eating burrows for itself into solid wood to the depth of about half an inch. These burrows are nearly round, and of all sizes up to about a sixteenth of an inch in diameter, and they go into the wood at all angles, and are usually more or less crooked. They are often so numerous as to reduce the wood to mere series of thin partitions between the holes. In this state the wood rapidly decays, or is washed away by the waves, and every new surface exposed is immediately attacked, so that layer after layer is rapidly removed, and the timber thus wastes away and is entirely destroyed in a few years. It destroys soft woods faster than hard ones, but all kinds are attacked except teak.



LIMNORIA LIGNORUM; DORSAL VIEW. ENLARGED TEN DIAMETERS.

It works chiefly in the softer parts of the wood, between the hard annual layers, and avoids the knots and lines of hard fiber connected with them, as well as rusted portions around nails that have been driven in, and consequently, as the timber wastes away under its attacks, these harder portions stand out in bold relief.

"'Where abundant, it will destroy soft timber at the rate of half an inch or more every year, thus diminishing the effective diameter of piles about an inch annually. Generally, however, the amount is probably not more than half this; but even at that rate the largest timbers will soon be destroyed especially when, as often happens, the *teredos* are aiding in this work of destruction. It lives in a pretty narrow zone, extending a short distance above and below low water mark. It occurs all along our coasts, from Long Island Sound to Nova Scotia. In the Bay of Fundy it often does great damage to the timbers and other woodwork used in constructing the brush fish weirs, as well as to the wharves, etc. At Wood's Holl it was found to be very destructive to the piles of the wharves.

The piles of the new government wharves have been protected by broad bands of tin plate covering the zone which it chiefly affects. North of Cape Cod, where the tides are much greater, this zone is broader and this remedy is not so easily applied. It does great damage also to ship timber floating in the docks, and greater losses are sometimes caused in this way. Complaints of such ravages in the navy yard at Portsmouth, N. H., have been made, and they also occur at the Charlestown navy yard and in the piles of the wharves at Boston. Probably the wharves and other submerged woodwork in all our seaports, from New York northward, are more or less injured by this creature, and, if it could be accurately estimated, the damage would be found surprisingly great.

" 'Unlike the *teredo,* this creature is a vegetarian, and eats the wood which it excavates, so that its boring operations provide it with both food and shelter. The burrows are made by means of its stout mandibles or jaws. It is capable of swimming quite rapidly, and can leap backward suddenly by means of its tail. It can creep both forward and backward. Its legs are short and better adapted for moving up and down in its burrow than elsewhere, and its body is rounded, with parallel sides, and well adapted to its mode of life. When disturbed it will roll itself into a ball. The female carries seven to nine eggs or young in the incubatory pouch at one time.

" 'The destructive habits of this species were first brought prominently into notice in 1811, by the celebrated Robert Stephenson, who found it rapidly destroying the woodwork at the Bell Rock Lighthouse, erected by him on the coast of Scotland. Since that time it has been investigated, and its ravages have been described by numerous European writers. It is very destructive on the coast of Great Britain, where it is known as the "gribble." The remedies used to check its ravages are chiefly copper or other metallic sheathing; driving broad-headed iron nails, close together, into the part of the piles subject to their attacks, and applying coal-tar, creosote or verdigris paint once a year or oftener.' "

The city engineer's report further says: "The two remaining animals referred to are the *teredo navalis,* or ship worm, and the *chelura terebrans.* The *teredo* is found in warm climates in nearly all parts of the world. In appearance it is a large soft worm, and may grow to the length of 18 inches and to a diameter of $\frac{3}{8}$ inch; it burrows in the interior of the timber, and when it is numerous the timber is soon reduced to a mere shell. It is abundant on the southern coast of Massachusetts, but is not found north of Cape Cod."

Of the *chelura,* the authority already quoted says:

"This very destructive little crustacean, which is of common occurrence on the European coast, from Southern Norway to the Adriatic Sea, has so far been noticed on the Atlantic coast of the United States at only two places, Wood's Holl and Provincetown, Mass.

"At both of these localities it was found associated with the 'gribble' (*limnoria lignorum*), in the submerged piles of old wharves. It is more than possible, however, that it is a common inhabitant of our coast, doing a certain amount of the damage hitherto ascribed to other boring animals. Without a careful examination, it is quite easy for an unskilled eye to confound *chelura* with *limnoria,* although they belong to very distinct divisions of the *crustacea.*"

"Specimens of the timber secured by the diver from two localities infested by the *limnoria* were submitted to Prof. S. I. Smith, of New Haven (who first identified the *chelura* in this country), and to Professor Hyatt, of the Boston Society of Natural History, and were carefully examined by them, but no specimens of the *chelura* were found. The sample of spruce timber examined was taken from Broadway Bridge, Boston, at a depth of about 14 feet below low water, and the oak timber came from Chelsea Street Bridge in East Boston, at a depth of about 20 feet at low water. The *limnoria* was abundant in each case."

The steamboat wharf at Deer Island, which was rebuilt in 1879 because of the ravages of the *limnoria,* had been built for twenty-four years. In rebuilding in 1879 larger oak piles were used, but a recent examination has shown that many of the piles have been practically destroyed. The wharf at Gallops Island, built in 1872, is also badly damaged, and many piles will be replaced this season. Wharves at Rainsfords and Long Islands also show serious injuries from the *limnoria.* On the other hand, oak piles in the upper harbor, where the water is more foul, resist much longer, and there are probably many piles in Cragie's Bridge which have been in service for more than a hundred years.

A reference to the inroad of the *teredo* in Boston harbor, alluded to by Mr. Hodgdon, was made in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, in the May number of the year 1894.

A paper by Charles H. Snow (*Transactions Am. Soc. C. E.,* vol. xl, 1898), on "Marine Wood Borers," gives a very complete account of the *teredo* and a less full account of the *limnoria* and other borers.



No. 1. No. 2.

No. 1. Spruce Pile Attacked by the Limnoria Terebrans. The Lower Part Shows the Pile Uninjured, where It was under the Mud.

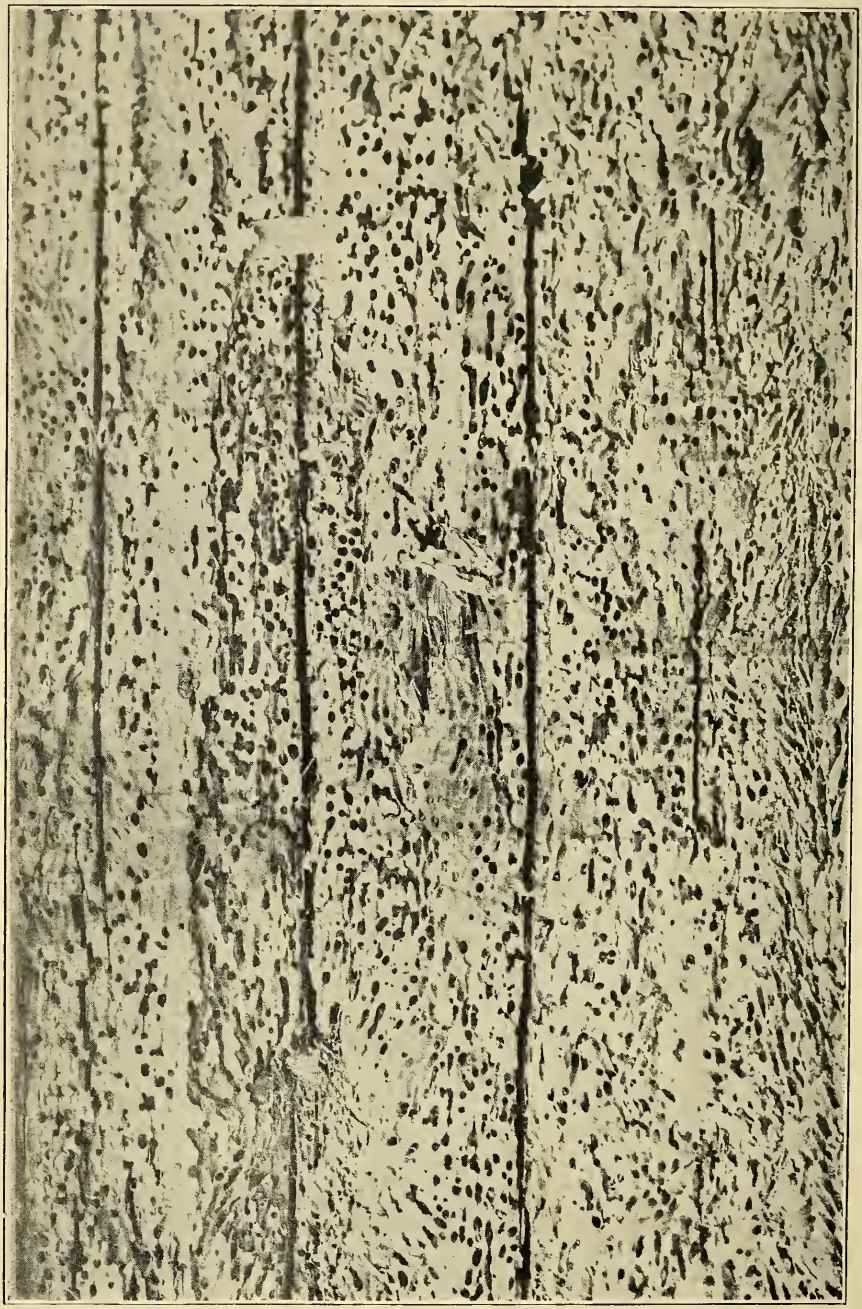
No. 2. Hard Pine Timber Attacked by the Limnoria.



Oak Pile 23 Feet Long, 16 Inches Diameter. Reduced in Size by the Limnoria Terebrans.



Spruce Piles Destroyed by the Limnoria Terebrans.



Surface of Spruce Pile Attacked by the Limnoria Terebrans. Full Size.

GOLDSCHMIDT METHOD OF METALLURGY AND HIGH TEMPERATURE PRODUCTION BY MEANS OF THERMITE.

By B. Palmer Caldwell, Assistant Professor of Chemistry, Tulane University.

[Read before the Louisiana Engineering Society, May 11, 1903.*]

The notice which has been sent you of this meeting of the Louisiana Engineering Society has stated that I would talk to you about the Goldschmidt method of metallurgy and high temperature production by means of thermite. I am afraid that I may be opening up a subject that is more or less old to some of you, as the daily papers have, within the last year, contained more than one account of the glowing possibilities awaiting the employment of this wonderful substance, thermite.

No sooner are discoveries made in any branch of science than the semi-scientific, semi-popular papers and, in a remarkably short time, the daily journals also light upon them and they form the subject of articles in which properties are ascribed to them far more wonderful than their discoverers had known, and brilliant futures predicted for them far rosier than their nearest friend had ever dared to dream. In proof of this, recall the reception given to Koch's lymph, to the Roentgen rays and very recently to radium and the whole family of radiferous substances.

Do not understand that I altogether condemn these journalistic efforts, for I do not. They are generally founded on a germ of truth, even though they appear to be wholly the product of a fertile imagination. Now, imagination is a good attribute for a scientist to cultivate; one thing is necessary, however, that the scientist draw a sharp line of separation between his facts and his fantasies.

And so thermite has recently had its turn.

The subject, as given, would naturally divide my talk into two parts; the first dealing with metallurgy, or the gaining of metals, by means of thermite; the second, the production of high temperatures by means of thermite. But, as the latter is merely the result of the heat liberated in the chemical reaction that causes the former, both parts must necessarily be considered together.

Now, what is thermite, and what is the nature of the chemical reaction which causes so much heat? Thermite is the name given to a mixture of iron oxide and the metal aluminium in a finely

*Manuscript received August 12, 1903.—Secretary, Ass'n of Eng. Socs.

divided condition. The reaction is the reduction of the oxide of iron to metallic iron by the aluminium which is oxidized to aluminium oxide. As represented by a chemical equation the reaction is:

$$2Al + Fe_2O_3 = Al_2O_3 + 2Fe,$$

or if the ferroso-ferric oxide is taken:

$$8Al + 4Fe_2O_3 = 4Al_2O_3 + 8Fe.$$

We have, then, the formation of metallic iron which is in the molten state beneath a layer of molten slag—the aluminium oxide or corundum.

Why does this reaction take place? Berthelot, whose work in the subject of thermo-chemistry is classical, expressed in his *"Essai de Mechanique Chimique"* (1. xxix) what he called the law of "maximum work": "Every chemical change accomplished without the addition of energy from without tends to the formation of that body, or system of bodies, the production of which is accompanied by the evolution of the maximum quantity of heat." This law he elsewhere states in other words as the "theorem of the necessity of reactions" thus: "Every chemical change, which can be accomplished without the aid of a preliminary action, or the addition of energy from without the system, necessarily occurs if it be accompanied by disengagement of heat." Thomsen, also, more than forty years ago, stated the law of "maximum work."

When viewed rigidly the law of maximum work is found wanting in some respects; nevertheless, the fact remains that when the physical conditions of comparable chemical processes are kept as nearly as possible constant, the process which involves the maximum production of heat very frequently occurs in preference to other processes, or occurs to a considerably greater extent than any of these other processes.

In the reaction before us, then, we may compare the heats of formation of, say, aluminium oxide and iron oxide from their respective elements. If the former is greater we may expect the decomposition of iron oxide by aluminium; if the latter is greater, the reverse reaction will take place. But first let me explain a term which is perhaps a technical one. What is meant by the heat of oxidation? The heat of oxidation of a substance is the quantity of heat produced by the complete oxidation of that substance to form those masses of the products of oxidation which are represented by the chemical formulæ of these products—in other words, the quantity of heat liberated in the combustion of chemically comparable quantities of combustible substances to the formation of chemically comparable quantities of the products of oxidation.

Let us therefore compare the heats of formation of iron oxide (Fe_2O_3) and aluminium oxide (Al_2O_3).

Oxide.	Heat in Calories.
$Al_2O_3 3H_2O$	594.0
$Fe_2O_3 3H_2O$	396.4

The difference is nearly 200 calories. By the law of maximum work we should expect the reaction to go as has been indicated. Experiment shows that it does, and that iron oxide is reduced by metallic aluminium to metallic iron; and a large quantity of heat is evolved in the reaction.

So much then for the reaction between iron oxide and metallic aluminium.

If this reaction takes place between these two substances (metal and oxide), does it also take place between others? One answer to this question is the trial of the experiment. But a study of the heats of formation of other oxides and the comparison of them with that of aluminium oxide will also serve the same purpose.

I will give the heats of formation of some oxides of metals and of a few oxides of non-metals. A comparison shows that the heat liberated in the formation of aluminium oxide (Al_2O_3) is far greater than in these cases, and hence, according to the law of maximum work, the tendency for that compound to be formed is very great. And experiment shows that the reaction does take place.

TABLE OF HEATS OF FORMATION OF CERTAIN OXIDES OF METALS AND NON-METALS.

Oxide.	Heat in Calories.
$Al_2O_3 3H_2O$	594.0
H_2O (solid)	69.8
N_2O_5 (solid)	13.1
SO_2 (gaseous)	71.0
CO_2 (gaseous)	94.3
$Fe_2O_3 3H_2O$	396.4
$MnOH_2O$	94.8
CaO	131.0
$CaOH_2O$	214.9
SrO	128.0
$SrOH_2O$	214.5
ZnO	85.3
$ZnOH_2O$	82.7
$NiOH_2O$	60.8
$CoOH_2O$	63.4
CuO	37.2

This then covers the metallurgical side of my subject. Of course, you engineers will immediately ask about the costs, and no

thought is necessary to make you see that this method of production of, *e.g.,* iron would so far exceed in cost the ordinary method of reduction of the ore with coke, that its employment for the commercial production of iron is an impossibility, and doubtless always will be. But there is one point to be considered; iron made by the ordinary smelting process is never pure, but contains varying quantities of carbon, some combined in the shape of carbides, the rest graphitic. This iron is pure enough for all the ordinary purposes for which it is intended, but often pure iron is desired, and this thermite method gives it. In the obtaining of other metals like chromium, manganese, cobalt, nickel, which command higher prices, especially those which are used to impart certain properties to iron, this method may be of some commercial value.

It is the other side of the subject that promises more to the engineer, viz., the production of high temperatures, and to that I now turn.

We have seen that in the reaction between metallic aluminium and iron oxide a large *quantity of heat* is liberated. Now, if this heat can be confined within a small space, and is liberated all in a short time, then the *intensity* increases and we have *high temperature.* These two points: (1) The production of the heat through a confined space, and (2) the instantaneous production of it are fully met, so that we have in thermite a notable producer of high temperatures.

Goldschmidt claims that in a suitably constructed and yet simple apparatus a temperature of 3000° Centigrade or 7200° Fahrenheit can be obtained. The temperature of the electric arc has been variously estimated; it is probably between 3000° and 3500° C. The temperature reached in an electric furnace probably does not exceed 1500°-2000° C. But the most important point is that this temperature of 3000° can be obtained by means of thermite in an instant of time, and can be applied conveniently over as small space as desired.

It is to this feature that I would especially call your attention. I am aware that most of you are not mechanical but civil engineers. But you may at any time be called upon to exercise the function of a mechanical, electrical, chemical, architectural or any other kind of an engineer; and I believe it can be truly said of the civil engineer that, chameleon-like, he changes his color quickly and naturally, and appears to advantage in all.

The application of thermite as a heat producer has so far been made to problems of iron welding, especially the welding of street car rails *in situ,* bridge beams and structural iron of all sorts, pipes,

etc. The temperature of fusion of iron is around 1600° C., which is far below the 3000° claimed for this reaction. Other processes which require heat will readily suggest themselves to you, in which the application of thermite may prove advantageous.

A word should be said about the manipulation of the substances. In the production of metals the ore [oxide] is mixed with finely divided metallic aluminium and the mixture placed in some receptacle as a Hessian crucible. On the surface of the mixture is placed a little "kindling mixture," which is itself a mixture of barium peroxide and aluminium. On this is placed a "cartridge," which is a little pellet of the "kindling mixture" with an inch strip of magnesium ribbon sticking out from its center. The magnesium ribbon is lighted with a match, and burns with the evolution of some heat. This heat serves to start the reaction between the barium peroxide and the metallic aluminium which evolves a larger quantity of heat. This heat suffices to start the main reaction—between the metallic aluminium and the oxide—which proceeds throughout the whole mass of the mixture with the evolution of a large quantity of heat. The crucible may now be turned upside down, and the molten metal will pour out together with the molten slag—aluminium oxide or corundum. Or the crucible may be allowed to cool when it may be broken off with the solidified slag, leaving an ingot or button of the metal. In the use of thermite as a heat producer the manipulation is practically the same, varying with the nature and size of the pieces welded. Usually the parts are surrounded at the point of junction with sand, firebricks, etc., to confine the heat and the thermite is placed within this improvised furnace.

The production of thermite is controlled by patents in all civilized countries; the substances can be obtained from the Chemische Thermo-Industrie G. m. b. H., Essen-Ruhr, Germany. In Germany the prices are: Thermite, 3.75 mk. per kilo.: kindling mixture, 6 mk. per kilo.; cartridges, 5.50 mk. per hundred.

The following demonstrations were made before the society:

1. The making of carbon-free iron.
2. The making of carbon-free manganese.
3. The making of carbon-free cobalt.
4. The making of carbon-free nickel.
5. The making of carbon-free chromium.
6. The heating of an iron plate.

An iron plate ¾ inch thick was placed upon supports so that its underside could be seen. The thermite mixture was placed upon it in the space between three bricks and fired in the usual

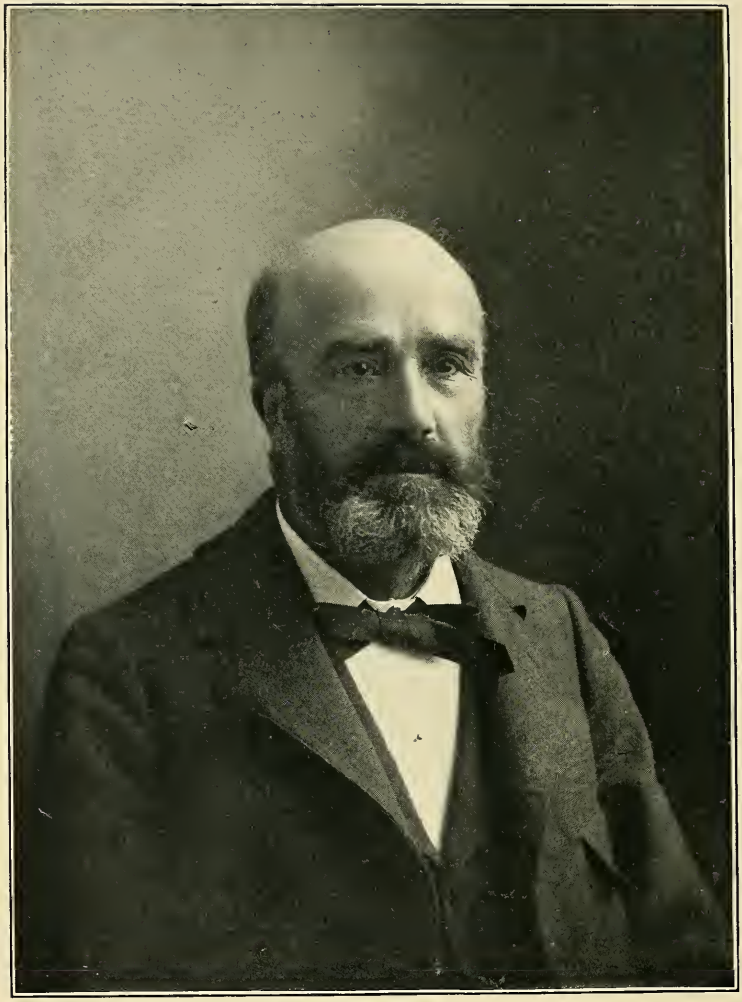
way. Immediately the underside of the plate became red, then white hot below where the reaction was taking place, while 2 inches away or less the plate was perfectly cold.

7. The melting of iron.

Some of the thermite mixture was placed in the bottom of a small Hessian crucible, and into this was pressed a rod of iron $\frac{1}{4}$ inch in diameter. The mixture was then fired. The rod melted down like wax.

See *Marine Engineering,* June, 1903, p. 329, for accounts of application of thermite to ship repair.

The American agent of the Thermite Company is Mr. C. B. Schultz, 149 Broadway, New York.



AUGUST H. SCHIERHOLZ.

Mechanical Engineer. Late Member Technical Society of the Pacific Coast.

INDEXED

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THE HEYLAND INDUCTION MOTOR.

BY A. S. LANGSDORF.

[Read before the Engineers' Club of St. Louis, June 3, 1903.*]

DURING the last few years the technical journals have contained frequent accounts of the invention by Mr. Heyland of a form of induction motor which operates at unity power factor. The published articles, however, have been so scattered that it has appeared desirable to the writer to present the subject to the members of this Club in connected form.† The theory of operation of the Heyland motor is, however, so intimately connected with that of the ordinary type that a brief review of the principles of the latter is included as a part of the description of the former.

From the standpoint of mechanical operation, the polyphase induction motor closely resembles the ordinary continuous current shunt motor; for example, in their common tendency towards constant speed with constant impressed e.m.f.; in the improvement of speed regulation effected by reducing armature resistance, and in the feature of a practically constant field at all loads.

In fact, the induction motor may be regarded from one point of view as an evolution of the shunt motor. For it is well known that a D. C. shunt motor preserves the same direction of rotation, irrespective of the direction of the current in the supply circuit; theoretically, therefore, the shunt motor would continue to rotate in

*Manuscript received September 25, 1903.—Secretary, Ass'n of Eng. Socs.

†This paper had been prepared before the writer received a copy of an article on the same subject by Professor C. A. Adams, published in the *Transactions of the American Institute of Electrical Engineers,* Vol. XX, p. 761.

the same direction whether the impressed e.m.f. remains uni-directional or whether it continually reverses; thus, in the limit, if the reversals are rapid and periodic, the motor would be operating on an alternating current supply. Practically, however, this would introduce great complications, and the motor would either spark viciously or refuse to operate at all. For, in the above discussion, it is assumed that currents in the armature and the field circuit reverse simultaneously, which cannot be the case when the impressed e.m.f. is rapidly alternating; here the effect of self-induction, or magneto-electric inertia, disturbs the otherwise simple action. The armature consists of relatively few turns of wire, while the field has very many; the choking action of the armature upon the current is, therefore, very much less than that of the field circuit, so that the current through the armature will alternate nearly in unison with the alternations of the impressed e.m.f., while that through the field will not. As a matter of fact, the field current would lag in phase behind the e.m.f. by nearly a quarter of a period, only reaching a maximum after the armature current has passed its largest value and has fallen to nearly zero. The result is that when the magnetic field, fluctuating in unison with the field current, is a maximum, and, therefore, best suited to produce a torque, there is little or no armature current to react on that field, and hence there is little or no torque. Torque, or turning moment, is proportional to the product of corresponding values of field strength and armature current; in

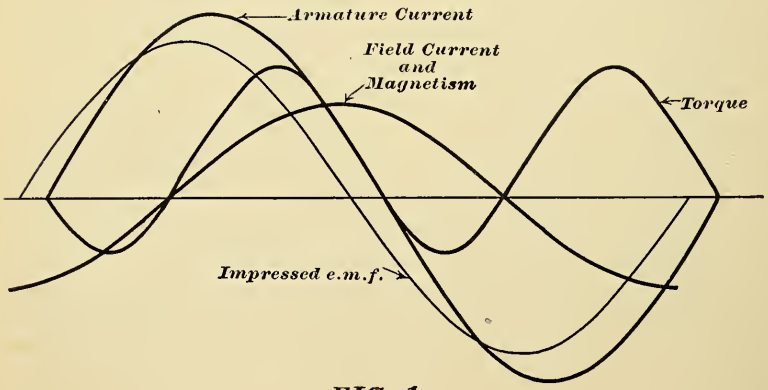


FIG. 1

Fig. 1, curve A represents the variations in this product through one complete cycle of changes, which shows that upon the whole the torque is as much negative as positive.

However, a consideration of this figure shows that this trouble may be cured by supplying the field and armature from independ-

ent circuits, whose alternations are out of phase with respect to each other by a quarter of a period. In Fig. 2, for instance, if

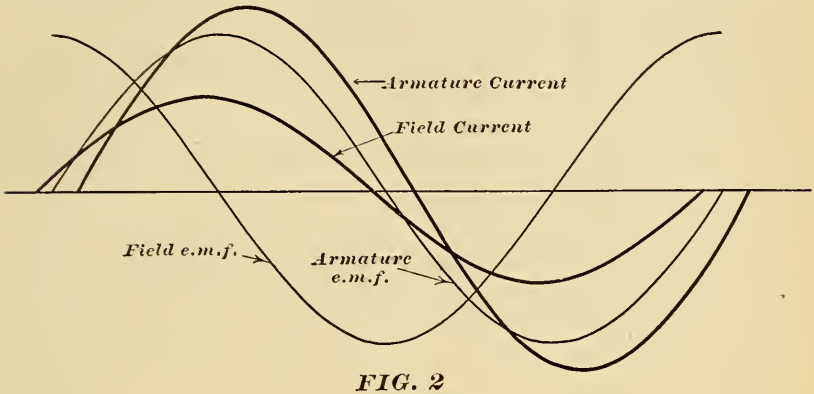


FIG. 2

the alternating e.m.f. impressed upon the field circuit is a quarter of a period ahead of the corresponding armature e.m.f., the resultant field magnetism and armature current will be in phase, or nearly so, thus yielding a torque which is mainly positive in value. This method is, therefore, equivalent to the use of a two-phase supply circuit.

Although the above-outlined plan effects an increased torque and, therefore, a greater output, it still fails to obviate the serious evil of sparking at the commutator. To get around this difficulty it is necessary to take the bull by the horns and do away with the

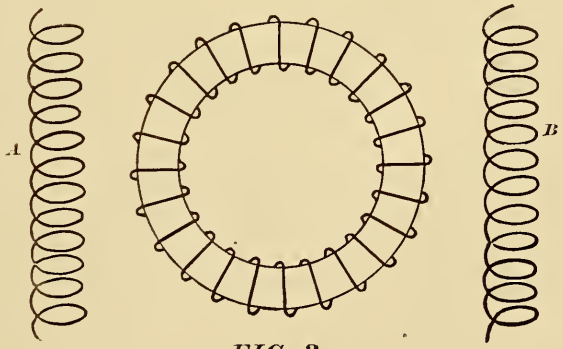


FIG. 3

commutator altogether When this is done, the necessary flow of current in the armature conductors is effected by utilizing the phenomenon of magneto-electric induction familiarly exemplified in the ordinary static transformer. To accomplish this the armature is wound with a closed coil winding, or even with the ordinary

squirrel-cage arrangement of conductors, and is surrounded by a coil, or group of coils, connected to one of the two supply phases. Thus, as in Fig. 3, the armature is surrounded by two windings, one of which, connected to phase A, furnishes the field magnetism; the other, connected to phase B, carries the energy current, which, after the ordinary transformer action, reappears in the armature.

This arrangement is still defective in that it loads the two phases, A and B, unequally, for A carries merely the small magnetizing current, while B carries the much larger current to be transformed into mechanical energy.

The next step in the improvement of the operation must, therefore, be directed towards an equalization of the current consumption in the two phases. This might be done in the following manner:

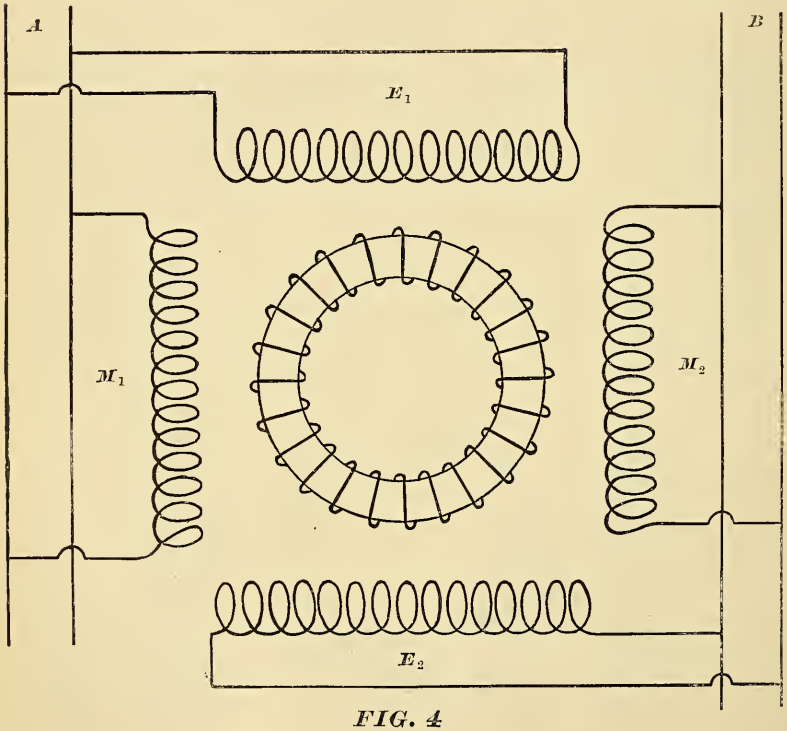


FIG. 4

Wind the armature as before, but surround it with four coils, connected to phases A and B, as indicated in Fig. 4. The pair of windings M_1 and E_2 now act together as in the previous case, while M_2 and E_1 act similarly in all respects, thus dividing the total action between the two pair. Each phase is now equally loaded, since each provides half of the magnetizing and energy currents.

The resultant effect, however, would be precisely the same if the original two coils only were used. For since M_1 and E_1, and similarly M_2 and E_2, are in parallel, they are equivalent to a single coil; if we think of them, therefore, as thus combined, each of the two resultant coils would carry a current whose components are the magnetizing current of one phase and the energy current of the other.

We have now arrived at a point where the ordinary shunt motor has been evolved into the well-known two-phase induction motor; in the process the mechanical characteristics of the former have been retained, while there have been introduced many of the electrical features of the ordinary static transformer. This treatment of the two-phase motor may be as readily extended to include the three-phase type; the difference is only one of degree and not of kind.

It now remains to examine more in detail the various currents and e.m.f.'s encountered in the operation of the polyphase induction motor. The starting point in the investigation is the field magnetism, which is somewhat more complex than the simple, to-and-fro, alternating flux which would exist, for example, in the case illustrated by Figs. 1 and 2. For, instead of a single magnetizing coil, we now have two or more, each of which tends to produce its own independent alternating field; these hypothetical independent fields combine to form the actual field, which is not alternating in space, but rotating at a uniform speed, as can be proved both experimentally and mathematically. The case of the two-phase motor, for instance, is strictly analogous to that of a pendulum subjected to two periodic impulses acting at right angles to one another in space and having a phase difference in time of a quarter period. This resultant rotating field in sweeping around the air-gap cuts across the armature conductors, and thereby induces in them the currents which react upon the field to produce the torque. The armature in its rotation tends to keep pace with the revolving field, *i. e.*, to run in synchronism; truly synchronous speed can never be attained, however, for, if such were the case, a given armature conductor would always be in a field of the same strength, no current could, therefore, be induced, and hence no torque would result. The conductors slip back in consequence by an amount just sufficient to develop the current necessary to carry the load, this slip being nearly proportional to the load, and rarely greater, at least for ordinary service, than 4 or 5 per cent.

This revolving flux is, of course, not of uniform intensity all around the air-gap, but shades off from point to point, forming a

succession of alternate north and south poles whose number depends upon the arrangement of the field coil windings. Any given fixed area in the air-gap is, therefore, threaded by magnetic lines of force passing through it first in one direction, then in the other, just as if the flux at that point was a simple alternating one. A conductor placed there will then have induced in it an alternating e.m.f., which, by the usual law, lags 90°, or a quarter period, behind the inducing flux.

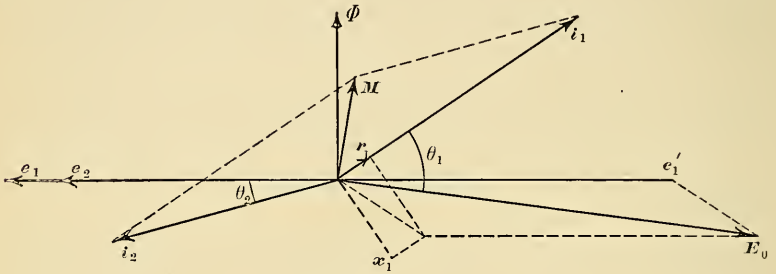


FIG. 5

The inducing flux, or field, is due to the resultant magnetizing actions of the currents in the field coils and in the armature windings. In Fig. 5, OΦ is this resultant field, while OM is the resultant magnetizing force of the field and armature currents, OM being slightly ahead of OΦ in phase due to hysteresis. This flux, as outlined above, induces e.m.f.'s in the field and in the armature, which lag 90° behind it and which are represented by the vectors Oe_1 and Oe_2, respectively. The armature induced e.m.f., Oe_2, produces the armature current, Oi_2, which lags somewhat in phase behind Oe_2 due to self-induction, or magnetic leakage. The primary current, Oi_1, is then found by the use of the parallelogram law of vector combination, since OM must be the resultant of Oi_1 and Oi_2.

The primary impressed e.m.f. must be of such magnitude and phase position that it will overcome (1) the e.m.f., Oe_1, induced by the revolving field, (2) the drop in voltage due to resistance of primary winding, Or_1, and (3) the e.m.f. induced by leakage flux, Ox_1. It is, therefore, equal to OE_0 in the figure, and has the phase position there shown, the construction being obvious.

In this figure, θ_1 is the angle by which the primary current lags behind the impressed e.m.f., and the cosine of this angle is the so-called power factor.

In order to have a high-power factor, therefore, θ_1 must be small. To keep θ_1 as small as possible means a reduction of θ_2 and X_1 to a minimum, or, in other words, a reduction of magnetic leak-

age, the latter being effected by making the air-gap as small as mechanical considerations will permit.

If we confine our attention to a motor in which magnetic leakage and ohmic resistance of primary are negligibly small, the diagram becomes much simplified, as in Fig. 6.

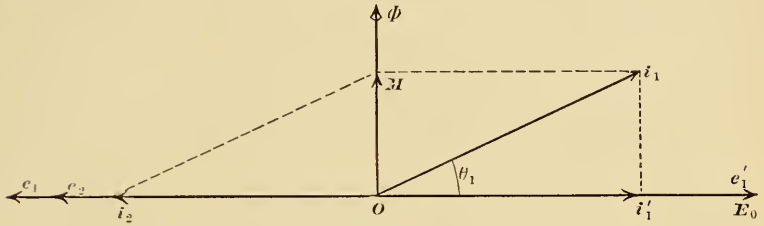


FIG. 6

Here, Oi_2 coincides with Oe_2 in phase, and Or_1 and Ox_1 vanish. The assumption is also made that OM is in phase with OΦ, which is very closely approximated in reality.

The useful power delivered by the motor is, in watts, the product of OE_0 by Oi'_1, the latter being the component of Oi_1 in phase with OE_0; the other component of current $i_1i'_1$, or wattless current, represents no power, but it requires just as much copper section per ampere as the useful current; and, in addition, it has a bad effect upon the voltage regulation of the system supplying the current. It is obvious that if $i_1i'_1$ can be eliminated, the angle θ_1 will become zero, its cosine, and, therefore, the power factor will become unity, and the characteristics of the system will be improved. This is the principal object of the invention of Mr. Heyland, now to be explained.

The heavy lines of Fig. 7 are a reproduction of part of Fig. 6. If θ_1 is to become zero, *i. e.*, Oi_1 shifted to Oi'_1, it is clear that Oi_2

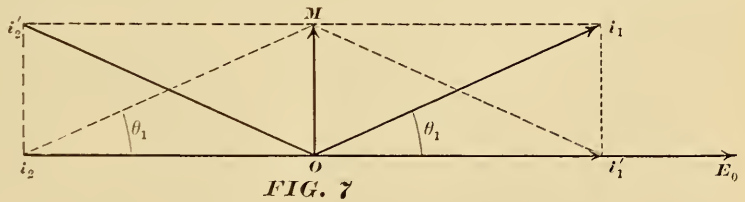


FIG. 7

must be at the same time shifted to Oi'_2, since their resultant must still be OM. This latter change may be effected by introducing into the armature conductors from some external source an auxiliary alternating current whose magnetizing force is represented in magnitude and phase by the line $i_1i'_2$. This result is accomplished by winding the armature with an ordinary closed coil wave winding, such as is

commonly used in D. C. machines, and adding a commutator at one end. At the other end the winding is tapped to collector rings, four of these being provided for two-phase, three for three-phase machines; these rings are then connected to variable resistances. It can thus be seen that the winding is a combination of the ordinary direct current winding and the short circuited or squirrel-cage arrangement so common in induction motors.

The auxiliary compensating current is introduced through the commutator by means of brushes; this current is obtained from the main line supply, and is accordingly an alternating current of the same frequency as that used in the primary or field winding. But the voltage of the supply circuit is in general much too high for driving the relatively small corrective current required, so an additional step-down transformer is required. Moreover, it can be seen that the auxiliary current should be 90° in phase away from that of the voltage of the line, so that, if it were introduced without other precaution, it would be in phase with the e.m.f. This, however, can be corrected by swinging the brushes through which it is introduced through a definite angle, the effect being to shift the phase of the magnetic field due to this current forward by an angle equal to that through which the brushes are swung backward, and vice versa. It need scarcely be added that the field due to this compensating current is a rotative one of the same frequency as that of the main field.

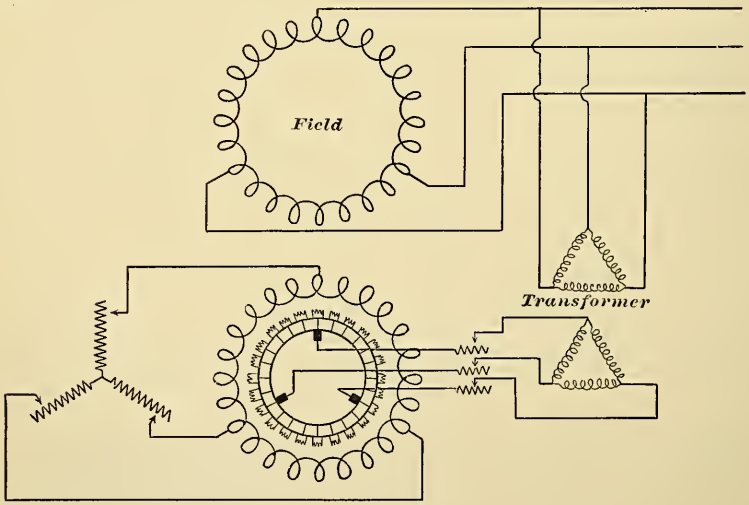


FIG. 8

The completed machine is shown diagrammatically in Fig. 8, for the case of a three-phase supply circuit.

There is another feature, however, which deserves attention. The brushes must, of course, be wide enough to span at least two commutator segments, so that when this happens an element of the winding is short-circuited through the low resistance of the brush. Since this element or coil of the winding carries an alternating current, vicious sparking results, just as in the case of any series wound alternating current motor. To partially overcome this, the gaps between adjacent segments are bridged by resistances of German silver wire, which act as shunts and absorb the energy of the inductive "kick," which would otherwise appear as an arc.

The Heyland motor is, therefore, like an ordinary induction motor, with the addition of a commutator, brushes and a short-circuiting band of relatively high resistance around the commutator. By proper regulation of the position of the brushes and of the voltage applied to them through the small step-down transformer, there may be obtained the advantage of a unity power factor, with its attendant features of greater economy of transmission and improved regulation of the system. By shifting the brushes still farther, a leading current may even be drawn, so that one of the advantageous features of the synchronous motor is added.

On the other hand, some serious disadvantages are introduced, notably the entire removal of the simplicity, which is such a valuable feature of the ordinary induction type. The addition of a commutator does away with the at least strong "talking point" so well known to prospective purchasers of electrical machinery, and prevents the use of this type in the neighborhood of explosive or highly inflammable materials. Again, an adjustment of power factor, which is correct for one load, is not necessarily so for others; consequently, a variable load requires more or less manipulation of the auxiliary brushes and of the rheostat which controls the e.m.f. of the compensating current. However, improvement of the operation of the motor will undoubtedly be effected as the results of experience bring to light the defects of design.

THE COST OF OPEN-HEARTH STEEL AS AFFECTED BY USING BLAST FURNACE GAS IN GAS ENGINES, AND REMARKS ON THE LATEST IMPROVEMENTS.

By Peter Eyermann.

[Read before the Civil Engineers' Club of Cleveland, September 22, 1903.*]

With the enormous development of the industries of the United States was combined the development of all the necessary appliances for the production and transportation of large quantities of iron ore, coal, coke, lime, slag, pig iron and Bessemer and open-hearth steel in all forms and sizes. At the same time all the marvelous installations of the new railway equipments and the fleets of ocean and lake steamers have been growing, and new inventions for the handling of material have astonished the world. The Brown ore-handling plants and gigantic loading cranes, together with the famous system of the three-motor traveling cranes and the scientific Wellman charging machine are wonderful results of a new mechanical science specially founded on electricity.

But, in spite of all these installations, whose original object was labor saving, the price of the open-hearth steel was not cheapened enough to enable it to compete with Bessemer or Thomas blown steel. And with this rapid progress the question of one special kind of steel was growing more important each day; this product, as it is well known to-day, is used more than any other metallurgical product in the world's consumption, and this is the open-hearth steel.

The writer has had the opportunity to study American and European practice, and has always been met by the question how open-hearth steel could be produced at a less cost and in larger quantities. Whenever he has seen the long rows of open-hearth furnaces, especially in the Pittsburg district, his first thought has been: "What would be done in case scrap should be scarce or the price of it should be too high?"

A new style of engineering has within the last few years come into the technical world. This is the important invention, from the other side of the ocean, of operating gas engines directly by blast-furnace gas; but of this scientific and practical question so much has been published within the last few years that it would be a waste of time to dwell long on its advantages.

*Manuscript received October 5, 1903.—Secretary, Ass'n of Eng. Socs.

The following are some important points in reference to gas engines:

There are to-day four types of gas engines especially preferred for the use of blast-furnace gas. The well-known four-cycle single-acting gas engine (Seraing & Deutz) has, as a rule, the following dimensions:*

First. Stroke in inches per indicated horse power, $\frac{3}{5}$ for 100 horse power down to 5-64 for 800 horse power.

Second. Circumference of cylinder in inches per indicated horse power, 11-16 for 100 horse power down to 3-16 for 800 horse power.

Third. Piston area in square inches per indicated horse power, 4 for 100 horse power down to 2.65 for 80 horse power.

Fourth. Cylinder area equal to cylindrical surface and added to two piston areas, in square inches per indicated horse power, 25 for 100 horse power down to 15.5 for 800 horse power.

Fifth. Cylinder volume (stroke $\times$ piston area) in cubic inches per indicated horse power, 140 to 150 for 100 horse power down to 120 for 800 horse power.

Of double-acting four-cycle engines too few have thus far been put in use to enable us to make a definite statement of relative proportions as in the above case.

In the Oechelhauser type of double-cycle gas engine the joint travel of the two pistons is equal to two diameters of the crank. As a rule, the Oechelhauser has the following dimensions:

First. Stroke in inches per indicated horse power, 7-32 for 200 horse power down to 3-32 for 1000 horse power.

Second. Circumference of cylinder in inches per indicated horse power, $\frac{1}{3}$ for 200 horse power down to $\frac{1}{8}$ for 1000 horse power.

Third. Piston area in square inches per indicated horse power, 1 for 200 horse power to 1000 horse power.

Fourth. Cylinder area equal to cylindrical surface and added to two piston areas, in square inches per indicated horse power, 14 for 200 to 1000 horse power.

Fifth. Cylinder volume (stroke $\times$ piston area) in cubic inches per indicated horse power, 36 for 200 to 1000 horse power.

This system shows some advantages as compared with the first system.

The proportions of the Körting system, as given below, show some advantage in comparison with similar systems:

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*These figures are calculated from a large number of gas engines.

First. Stroke in inches per indicated horse power, 5-64 for 500 horse power down to 1-16 for 700 horse power.

Second. Circumference of cylinder in inches per indicated horse power, 9-64 average for 600 horse power.

Third. Piston area in square inches per indicated horse power, 0.92 average for 600 horse power.

Fourth. Cylinder area equal to cylindrical surface and added to two piston areas, in square inches per indicated horse power, 7.7 average for 600 horse power.

Fifth. Cylinder volume (stroke $\times$ piston area) in cubic inches per indicated horse power, 44 average for 600 horse power.

The writer is working on a new gas engine, and he expects to reduce considerably the dimensions above given, especially the cylinder area, which he expects to reduce to about 6 square inches, and the cylinder volume to about 25 cubic inches per horse power.

It is to be hoped that the most dangerous installation in all power plants, namely, the steam boiler, will disappear entirely, not alone in the blast furnace, but also, with the improvements in gas producing, in other industrial and manufacturing plants. There remains to be solved only the problem of the right type of gas producer suitable for each quality of coal and producing a power gas free from tar and dust.

On May 7th of last year the writer had the opportunity of reading a paper on this subject before the Iron and Steel Institute in London. Since that time a patent, No. 723,594, has been granted in the United States for this invention, concerning a new process for producing steel.

I will not take up your time to-night by going fully into this subject, but will only state that the most important claim is the use of blast-furnace gas in the open-hearth furnace, either directly or enriched in a special regenerating gas producer. The writer shall feel satisfied if these lines result in discussions or in finding a blast-furnace plant for remodeling.

The writer recently received from one of the most important steel works in the United States a very interesting letter, and which will show how different are the opinions entertained on this subject.

The letter is as follows:

"In looking over your patent I find that it relates principally to the process of producing open-hearth steel, which consists in charging liquid pig iron directly from a blast furnace into an open-hearth furnace and heating this metal first by the combustion of poor blast-furnace gases and finally by the combustion of blast-

furnace gases which have been enriched by passing them through incandescent coke or similar material.

"This process seems to me to be impracticable for various reasons, but it will be sufficient to call your attention to the fact that to produce one ton of open-hearth steel requires the consumption of at least 700 or 800 pounds of good gas coal. Our blast furnace having no gas to spare beyond that made for the heating of the blast and of the production of steam, which later is to be helped out by the use of considerable quantity of steam coal. Besides this, the character of the blast-furnace gases is not such as to produce good effects in an open-hearth furnace. As our blast furnaces have no gas to spare to operate an open-hearth furnace, this alone is sufficient to dismiss the matter from further consideration."

The circumstances as described in this letter are the same in many steel works.

Why not save this wasted gas?

If there are needed 800 pounds or more coal for each ton of open-hearth steel, and if there are necessary, besides, large quantities of steam coal for driving the old-fashioned steam blowing engines; if this is no reason to look for improvements, what other reason could there be?

Influenced by all these considerations, the writer devoted much attention to the study of modern blast-furnace construction—not the metallurgical part, but the structural and mechanical appliances.

In the writer's opinion, the blast furnace of the future will be more important as a producer of gas than as a producer of pig iron, and therefore certain modifications may be introduced in order the better to fulfill the new requirements.

Without entering too closely into details, it may be of interest to refer here to a new form of charging appliance, consisting of a continuously working bucket elevator, which conveys the mixed charge and coke in smaller quantities than is usually the case, and tips it on to the bell. In this manner the distribution of the material in the furnace is the most uniform possible, and consequently great regularity in the evolution of the gases is assured. As a precaution against the unnecessary waste of gas, the throat of the furnace is provided with a bell of the ordinary form, below which is suspended a vertical revolving tube. Within the latter is a screw, which is also capable of independent rotation, down which the charge gradually slides into the furnace, and is thus distributed with perfect evenness. The surface of the screw might be made adjustable in an axial direction, and the revolving motion so arranged

as partially to compress the charge, thus forming a further preventive against the escape of gas. Outside, on the top, are fixed two cylinders in tandem fashion, filled with oil and fitted with plungers, which are suitably connected to the bell by means of levers. By this means the lowering and raising of the bell are effected automatically at certain intervals, the operation being aided only by the weight of the charge accumulated on the bell. This arrangement is an absolutely sure preventive of the escape of gas through the hopper. The drawing off of the gases takes place chiefly at the center of the furnace through a ring-shaped pipe which entirely encircles the vertical charging tube, and, as a precautionary measure against explosion, safety valves, opening outwards, are fitted on the sloping surface of the conical shell forming the cover. Further, it will be seen from the drawing of this "pig iron gas producer" that the main supporting frame of the furnace combines certain features of both German and American practice. In the author's opinion, the American plan of the loose shell is a very excellent one, also the system of water-cooling which extends right through the brickwork to the bosh walls. As regards the tuyeres, the elliptical form of opening for the nozzle (which has proved so efficient in the case of large cupolas) is perhaps the most suitable. It has often come under the author's notice that the rings encircling the furnace bosh, a special feature of American construction, are liable to burst from the strain caused by excessive heating, and it might therefore be an improvement to shape them so as to form reservoirs for cooling water. The whole of the lower framework stands free, and is not walled in by masonry, a plan which is greatly to be preferred, since it prevents the chilling of the furnace hearth by the formation of "bears." The great waste of water in cooling the lower portions of the brickwork, which so frequently occurs in closed masonry and cannot be controlled, is at any rate avoided by this means.

In the following calculation an effort will be made to show how it would be possible to reduce the coal consumption per ton of open-hearth steel, perhaps to 200 pounds or less; and not alone to reduce the coal consumption in the blast-furnace plant for the boilers, but to throw out these coal eaters completely, and to win, besides, enough power to sell it in the form of electricity or in the form of heating furnaces.

It would be very advantageous to have a central gas-improving station, combined with a central gas-cleaning station, but the discussion of this matter in detail would require too much space here.

The new furnace should be called the "Compound Furnace,"

because it combines the experiences of the Bessemer blowing process and those of the open-hearth process. The product may, therefore, be called "Compound Steel."

The following calculation is based on practically known numbers. It is a continuation of the theoretical calculation of Mr. Toldt, read before the Iron and Steel Institute.

It will only be a rough outline sketch, showing what an important plant a blast furnace is:

Calculated self cost for one ton "Compound Steel" produced with the patent process No. 723,594:

First. This combined blast furnace and steel plant uses only modern gas engines. The boiler-house does not exist, and the necessary gas producers, including the blast furnace, are supplied with not only good coke, but all kinds of coke, and, if possible, some kinds of coal. The mixer, the long rows of open hearths, and the separate blowing-engine house are entirely dispensed with. Instead of high-priced scrap, more and cheaper high-grade iron ores and metal directly poured from the blast furnace will be used.

If there is a blast furnace of 500 tons daily capacity, or rather two furnaces of 250 tons each, if there is no other furnace in the neighborhood, an average of 500 tons of coke is used for the production of these 500 tons of pig iron.

$$\frac{500}{24} = \text{nearly } 21 \text{ tons of pig iron per hour.} \qquad (1)$$

Second. One ton of coke charged into the blast furnace is equal to 4600 cubic meters of gas. This was carefully measured and calculated for the European coke, but for the better American coke a little more gas will be produced, because it is intended to charge more coal and coke into the blast furnace than would be necessary to produce pig iron alone.

In this case the pig-iron producer must also be a gas producer at the same time.

While writing this calculation the writer received from Mr. Uehling a paper, wherein he calculates the quantity of gas for each ton of pig iron at about 10,600 pounds. It can therefore be seen that it will not be very far from a large average to base the following calculation on 5000 cubic meters of blast-furnace gas produced from each ton of coke charged. This is equal to 175,000 cubic feet of gas per hour.

500 tons $\times$ 5000 cubic meters $=$ 2,500,000 cubic meters of gas per day.

$\frac{2,500,000}{24} =$ 105,000 cubic meters of gas per hour, or 3,675,000 cubic feet of gas.

The same result is obtained by multiplying 21 tons by 5000 cubic meters = 105,000 cubic meters of gas per hour. (2)

This quantity of gas is free for use on any kind of work or for selling, but the most important use will be:

Third. For burning the coke in the blast furnace there is blown in, by the blowing engines, for each kilogram of coke, six cubic meters of air per hour; therefore for 21 kilograms of coke there are necessary 21,000 × 6 = 126,000 cubic meters of air per hour, or 2100 cubic meters of air per minute.

Experience shows that nearly 1.3 horse power per cubic meter of pressed air is necessary. This number may be increased to 1.5 horse power for modern plants.

$$2100 \times 1.5 = 3150 \text{ horse power per hour.}$$

For 1 horse power per hour, in a new gas furnace, there are required only 3 cubic meters of gas; or, $\frac{3}{60} = 0.05$ cubic meter of gas per minute = 105 cubic feet of gas per hour. 3150 horse power × 0.05 cubic meter = 157.5 cubic meters of gas per minute. 157.5 × 60 = 9450 cubic meters of gas per hour = 330,750 cubic feet of gas per hour.

The gas above mentioned will be named "Blowing-engine Gas." (3)

Fourth. Careful measurement shows that in existing plants nearly 10 per cent. loss of blast-furnace gas may occur. The loss will be in the pipes at the top, in the dust catcher, by charging ore and coke during the lifting of the bell, etc.; therefore, the next important point will be 10,500 cubic meters of gas per hour = 367,500 cubic feet of gas per hour.

This will be called "Furnace-loss Gas." (4)

Fifth. It would be advisable, not only in the new blast-furnace plants, but also in old plants, to clean all the gas in one central cleaning station. It is known that for each cubic meter of gas to be cleaned there are necessary 0.01 to 0.025 horse power per hour, or for each 1000 cubic feet of gas, 0.3 to 0.75 horse power per hour. One horse power requires 3 cubic meters or 105 cubic feet of gas per hour; therefore, 105,000 × 0.02 = 2100 horse power per hour, or 2100 × 6300 cubic meters of gas per hour, or 220,500 cubic feet.

This will be called "Cleaning-engine Gas." (5)

Sixth. It is certainly to be expected that not more than 25 per cent. of the gas will be used for heating the air in the stoves, if all is cleaned. In earlier years this percentage was much greater,

but with the cleaned gas there can surely be obtained 105,000 × 0.25 = 26,250 cubic meters of gas per hour, or 818,750 cubic feet.

This will be called the "Blast-heating Gas." (6)

Seventh. It is important to observe that under modern conditions this combined steel and blast-furnace plant needs from 100 to 120 horse power for each 100 tons daily capacity for the electric generating plant.

This electricity will be used for all electric-handling machinery and for electric illumination. For 500 tons per day there are needed 120 × 5 = 600 horse power.

Each horse power consumes 3 cubic meters of gas per hour, or 105 cubic feet; therefore 600 × 3 = 1800 cubic meters of gas per hour, or 63,000 cubic feet.

This will be called "Electric-generating Gas." (7)

Eighth. Directly in combination with the blast-furnace plant should be the compound steel furnace. In an open-hearth furnace of the general style the average for each ton of steel is 300 kilograms of good coal, or nearly 675 pounds per ton. These 675 pounds are specially needed where many steel ingots are poured. This quantity of coal is equal to 1500 cubic meters of producer gas.

There are 21 tons of pig iron to be converted into steel each hour. For this there are used 21 × 1500 = 31,500 cubic meters of producer gas.

The difference of units between the producer gas and the gas from the blast furnace is only from 100 to 200 calories per cubic meter, or 10 to 20 B. T. U. per cubic foot.

It will, therefore, be sufficient for this rough calculation to accept this number also for the compound furnace, as it is intended to work only three-fourths or two-thirds of the whole heating time with blast-furnace gas directly. During other parts of the heating time there will be used coke gas from the attached producer, mixed with improved blast-furnace gas. The latter is better than any producer gas, because it has up to 1500 calories per cubic meter, or 170 B. T. U. per cubic foot; therefore, 31,500 × $\frac{2}{3}$ = 21,000 cubic meters, or 735,000 cubic feet of gas are used in the compound furnace.

This may be called "Compound-steel Gas." (8)

Ninth. One of the most important ideas in this patent is the use of the blast of the blast furnace directly in the open-hearth furnace.

With this air the first rough fining of the metal should be done; therefore, a certain horse power is more necessary for driving blowing engines than is necessary for the blast-furnace plant alone.

This refining blast can be taken directly from the main pipe, hot or cold.

Finishing, for example, 20 tons of steel in a general Bessemer or Thomas plant, there are needed nearly 1000 to 1200 cubic meters of air.

If, as in this patent, only a rough fining is necessary, it will probably not be wrong to say 300 to 500 cubic meters for these 20 tons, or 15 to 25 cubic meters per ton of steel.

Taking 25 cubic meters, and remembering that there are 21 tons per hour to the fining, this will be:

$$21 \times 25 = 525 \text{ cubic meters of blast.}$$

For each cubic meter there are necessary from 1 to 1½ horse power per hour, if the pressure above stated is sufficient. Each horse power needs again 3 cubic meters of gas in the gas engine; therefore, $525 \times 3 \times 1.5 = 1575 \times 1.5 = 2362$ cubic meters, or 82,690 cubic feet of gas.

This will be called "Fining-blast Gas." (9)

Tenth. Under "eighth" we obtained 31,500 cubic meters of gas. Of this only 21,000 have been used directly in the furnace, there remaining 10,500 cubic meters for improving purposes; but it is possible that only 6000 cubic meters are needed for regenerating in the coke stoves.

Some blast-furnace gas can also be used for heating the ladles for burning fireproof materials, besides some loss in the valves, dampers and pipes, which will occur.

Together with the 6000 cubic meters, we may calculate here 10,500 cubic meters, or 367,500 cubic feet, of gas per hour.

This will be called "Steel-loss Gas." (10)

Eleventh. To complete this outline of the modern steel plant, it is important to state that there are in use other methods of converting by-product into money:

(a) The use of coke-oven gas, in the common way or in the compound-steel plant.

(b) The manufacture of bricks from the blast-furnace slag.

(c) The installation of a burning and milling factory for Portland cement.

To calculate these economies here would require too much space, but we may estimate them at an average of $1 to $2 per ton of pig iron, according to circumstances. (11)

Twelfth. The future of such a steel plant does not depend upon the quality of the iron ore as do the Bessemer plants of to-day. If no high-grade silicon pig iron is to be obtained, then high-phos-

phorus iron is also convenient. All grades of pig iron and ore can be used directly in this "Compound-furnace Plant," and scrap only when it is very cheap.

If the local conditions are favorable, it may also be possible to produce basic slag. This by-product can be sold as a fertilizer, saving from 50 cents to $1 per ton of steel. (12)

Thirteenth. The following table gives a clear idea of the different uses of gas per hour.

Paragraphs 11 and 12 may be neglected, as they give only practical results, which have no influence in the following gas calculation:

(3) Blowing-engine gas, 9450 cubic meters, or 330,750 cubic feet.

(4) Furnace-loss gas, 10,500 cubic meters, or 367,500 cubic feet.

(5) Cleaning-engine gas, 6300 cubic meters, or 220,500 cubic feet.

(6) Blast-heating gas, 26,250 cubic meters, or 918,750 cubic feet.

(7) Electric-generating gas, 1800 cubic meters, or 63,000 cubic feet.

(8) Compound-steel gas, 21,000 cubic meters, or 735,000 cubic feet.

(9) Fining-blast gas, 2362 cubic meters, or 82,610 cubic feet.

(10) Steel-loss gas, 10,500 cubic meters, or 367,500 cubic feet.

Per hour, 88,162 cubic meters, or 3,085,690 cubic feet. (13)

Fourteenth. The blast furnace has 105,000 cubic meters, or 3,673,000 cubic feet of gas free to sell per hour, which, after deducting 88,162 cubic meters, or 3,085,690 cubic feet, of gas, leaves 16,838 cubic meters, or 589,310 cubic feet, per hour. (14)

Fifteenth. The best way to sell power to-day is in the form of electric current. It can be obtained directly from gas engines. Each horse power requires 3 cubic meters or 105 cubic feet, of gas per hour.

$$\frac{16{,}838}{3} = 5600 \text{ horse power.}$$

In proportion to this electricity which is produced from coal in steam engines it certainly will not be too high to sell this furnace electricity for lighting purposes at 2 cents per kilowatt, or $5600 \times 0.746 = 4170$ kilowatts.

Now, assuming that in practical use only one-half of this power could be obtained,

$$\frac{4170 \times 2}{2} = 4170 \text{ cents, or } \$41.70 \text{ per hour.}$$

In each hour 21 tons of steel are produced; therefore there is a profit on 1 ton of steel of nearly $2 by selling electricity. (15)

Sixteenth. The superintendent of the blast-furnace plant would not give his gas to the steel plant for nothing. As seen above, each cubic meter of gas is worth 0.25 cent if sold in the form of electricity.

The steel plant needs the above three numbers, 21,000 ÷ 10,500 ÷ 2362 = 33,862 cubic meters of gas per hour.

It would probably only be possible under extraordinary circumstances to sell this gas at the same price as electric light; therefore, it would sometimes be better to sell it in large quantities in the form of electric power directly. In this case only 0.5 to 1 cent per kilowatt can be obtained.

This would be another theoretical profit of $\frac{33,800}{3} = 11,200$ horse power, or 8400 kilowatts. 8400 × 1 = 8400 cents; or, divided by 21 tons, = $4 per ton of pig iron; or, again, taking only half of this result, there will be a profit of $2 per ton of pig iron. (16)

Seventeenth. The blast-furnace plant can sell this gas cheaper if no electric generating engines are necessary; if sold as gas, it is to be noted that the heat efficiency of the blast-furnace gas is lower than that of the producer gas.

It is stated above that 1 cubic meter of gas, sold in the form of power, is worth 0.25 cent; but, when sold as gas directly, the writer will say only 0.1 cent up to 0.125 cent per cubic meter.

33,862 cubic meters, or 1,185,190 cubic feet, give, therefore, $33.862, or $42.50 profit per hour for the blast furnace.

In each hour 21 tons are produced; therefore, there is a profit of from $1.60 to $2 per ton of pig iron. (17)

Eighteenth. Before closing this calculation it will be interesting to compare the cost of operating a European 15-ton open-hearth furnace, using good German coal:

(a) Coal for gas in the producers, including small quantities of steam coal—480 pfennige, or 120 cents, per ton.

(b) Loss of combustion of the hearth—500 pfennige, or 125 cents, per ton.

(c) Firebrick, limestone, dolomite—200 pfennige, or 50 cents, per ton.

(d) Repairing cranes, etc.—80 pfennige, or 20 cents, per ton.

(e) Molds, bottom plates—180 pfennige, or 45 cents, per ton.

(f) Fluxes and special iron—40 pfennige, or 10 cents, per ton.

(g) Wear of the installation—300 pfennige, or 75 cents, per ton.

(h) Salaries—440 pfennige, or 110 cents, per ton.

Total—2220 pfennige, or 555 cents, per ton.

The cost of converting 1 ton of charges in open-hearth steel is, therefore, $5.55. (18)

Nineteenth. In a furnace of 200 tons capacity, and working continuously, the approximate cost of 1 ton of steel ingots will be only 1300 pfennige or less. (See paper read before the Iron and Steel Institute, London, May 7, 1902.) It will be interesting to compare these points with the following calculation.

Here it must be said that it was proposed to use the 200-ton furnace some years before, without the knowledge that Jones & Laughlins, of Pittsburg, have been erecting, in the meantime, a furnace of this capacity.

It is clear that in the English patent the proposition was made to combine the new Talbot process with this blast-furnace gas process. It is to be hoped that such a combination may have good results.

(a) Coke and coal for improving blast-furnace gas and producing coke gas—160 pfennige, or 40 cents, per ton.

(b) Loss of the hearth—320 pfennige, or 80 cents, per ton.

(c) Firebrick, lime, dolomite, magnesite—140 pfennige, or 35 cents, per ton.

(d) Repairs—60 pfennige, or 15 cents, per ton.

(e) Molds, bottom plates—160 pfennige, or 40 cents, per ton.

(f) Fluxes and special iron—80 pfennige, or 20 cents, per ton.

(g) Wear of the installation—200 pfennige, or 50 cents, per ton.

(h) Salaries—100 pfennige, or 25 cents, per ton.

Total—1220 pfennige, or 305 cents, per ton.

The difference is 1000 pfennige, or $2.50 per ton of converted steel.

The iron ore is here calculated with the charge, and not in the way adopted by Mr. Talbot.

Referring to "b" and "e," both can be reduced under certain circumstances.

The cost of producing 1 ton of steel would be still lower if a basic fertilizer slag could be obtained. (19)

Twentieth. The cost for one ton of pig iron, produced from a modern blast-furnace plant, situated in the neighborhood of a large city, able to sell all its power in electricity and equipped only with gas engines, would be very low. By adding together the figures given in paragraphs 15 and 16, we find that there would be a profit of $4 on each ton of pig iron; but under certain conditions only $2 profit. This profit can be nearly guaranteed to-day wherever an old-fashioned blast-furnace and steel plant is remodeled for this purpose. (20)

Twenty-first. The cost of producing 1 ton of "Compound Steel" would be:

(a)	Gas of the blast furnace.....	$1.60
(b)	Converting cost	3.05
	Total	$4.65

To the above is to be added the cost of 1 ton of the charge (including the pig iron), and, as already shown, this is very low.

Excluding case 20, but referring to paragraphs 11, 12 and 15, it is certainly possible to make pig iron for $2 to $4 less per ton than it costs to-day. (21)

This calculation shows that open-hearth or compound steel can be produced, under good conditions, just as cheaply as pig iron to-day, or still cheaper in connection with the modern gas engine.

OBITUARY.

August H. Schierholz.

Member of the Technical Society of the Pacific Coast.

August H. Schierholz, a member of the Technical Society of the Pacific Coast, came to an untimely end through a street-car accident in San Francisco on September 2, 1902.

In this able engineer and thorough gentleman the Society has lost one of its most valued members, one who, in his extreme modesty, preferred to listen and absorb rather than to come forward and speak of himself and of his valuable experiences in lines that should have made him prominent. He was justly entitled to prominence.

Born on July 7, 1839, in Enger, Westphalia, Prussia, he received in his youth that thorough education and technical training which enabled him to follow successfully the practical career in store for him. After serving his one year in the Prussian army and participating as a volunteer in the war between Prussia and Denmark, a war that resulted in the final incorporation of Schleswig-Holstein into the kingdom of Prussia, he came to the United States, like many of the young and energetic men of his time, and made his first stay in Chicago.

It was in 1872 that he came to California, and soon after his arrival he was engaged by the Risdon Iron Works, and with that firm he remained almost constantly up to the time of the unfortunate accident that removed him from a sphere of usefulness to which he had devoted all these years and the best part of his manhood.

Some of the prominent works with which he has been connected may be named here to show the versatility of the man's genius:

The erection of a sawmill and plant on the Uintah Indian Reservation in Utah, 200 miles from Salt Lake City.

The reconstruction of the machinery for the Tiger and the Poorman mines in Idaho.

The various machinery and mechanical devices for the exploitation of the Comstock Lode are in great part the result of his untiring activity.

Many of the enterprises connected directly with the welfare and prosperity of the State, such as the water supply of the city of San Francisco, the agencies for navigating the coast and harbors of the Pacific, the development of the large resources in water power made available through electric transmission, have had, at some time

or other, the benefit of his practical sense, particularly in adapting them to existing conditions and circumstances, which has always called for men of superior ability and energy in this remote part of the world.

The Cane-Sugar Mill of the Honolulu Plantation, Oahu, Hawaiian Islands, and the Beet-Sugar Factory at Salinas, Cal., the largest and best equipped anywhere, were built under his mechanical supervision.

Unobtrusive manners and exceeding modesty were the principal characteristics of this remarkable man. These qualities alone prevented him from acquiring a very marked prominence in this community and in our Society. Many a younger member of our calling has had the benefit of his instruction while he was chief draughtsman for the Risdon Iron Works, and will remember with gratitude his readiness to impart whatever was required of his large store of experience.

His friendship was undemonstrative, but lasting. His preference, after the toil of the day, was for quiet enjoyment of nature and home; the latter tendency was manifest in the fact that he seldom went to any of his distant fields of labor without the thoughtful companion of his life—the wife who survives him.

One well qualified to judge this man, one who has been in professional contact with him for many years, who well knows the true value of the character and ability of the late August H. Schierholz, our Past President George W. Dickie, writes of him as follows:

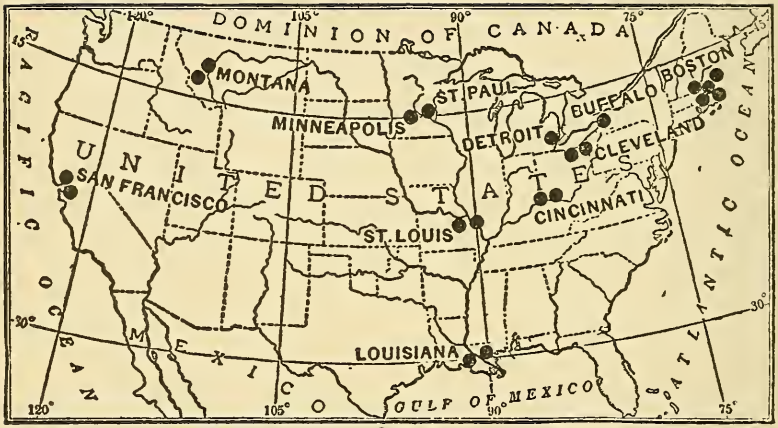
"Mr. Schierholz was one of those rare characters who had the ability to keep self in the background and devote all his power of mind to reaching the best solution of the problem he had in hand at the time. Only those who had a close, working acquaintance with this modest draughtsman could form any estimate of his work as a man and his great ability as a designer of mechanical structures. He had a rare faculty of seeing beneath the surface of the paper he was working on, and a simple elevation prepared by this talented man would convey all the information usually given by plans, elevations and numerous sections. He could give in a few hours one view of a complicated machine, showing all the parts in their relative positions for estimating purposes, which, when detailed out, would show that every part had its proper clearance, enabling the original design to be carried out as shown by his first picture of it. This faculty, so rare even in accomplished draughtsmen, gave to Mr. Schierholz's work a peculiar value, which enabled those fortunate enough to secure his services to present plans and

specifications of the most complicated work in a miraculously short time. And yet, with this faculty so valuable to an engineering business, his extreme modesty prevented him from making any true estimate of his own work.

"The writer had an intimate association with Mr. Schierholz for about twelve years, which was severed twenty years ago. He has, however, during these twenty years held Mr. Schierholz up, both to himself and to others, as a model draughtsman, wise in his profession and admirable in his character."

The Technical Society mourns the loss of this member and adds this as a fitting memorial to a man who, fully identified with the Pacific Coast, will not be forgotten, for his impression has been made and will be found far and wide wherever Mr. Schierholz has been and where his genius has found expression.

A. D'ERLACH,
Committee.


DOMINION OF CANADA
MONTANA
ST. PAUL
BUFFALO
BOSTON
MINNEAPOLIS
DETROIT
CLEVELAND
UNITED STATES
SAN FRANCISCO
CINCINNATI
ST. LOUIS
LOUISIANA
MEXICO
GULF OF MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN
120°
105°
90°
75°
30°



GEORGE FREDERICK ALLARDT.

Civil Engineer. Late Member Technical Society of the Pacific Coast.

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GAS.

BY THOMAS D. MILLER, MEMBER LOUISIANA ENGINEERING SOCIETY.

[Read before the Society, April 3, 1903.*]

THE Century Dictionary contains the following biographical note:

"Murdock, William. Born at Auchinleck, Ayrshire, August 21, 1754. Died at Birmingham, November 15, 1839. A Scotch inventor. He entered the works of Boulton & Watts, Birmingham, in 1777, and in 1795 made the first practical use of illuminating gas. He also invented the oscillating steam engine."

From the day that Murdock discovered coal gas and applied it to illuminating purposes, over a century ago to the present time, there has been a steady improvement in the methods and appliances for the manufacture, distribution, sale and use of illuminating gas. After Murdock's discovery, inventors were at work perfecting the furnaces to supply the heat to distil the gas from the coal; means for the extraction of the coal tar and other impurities had to be devised; and the storage and distribution of the gas through pipes required great ingenuity at that time. The measurement of the gas was a perplexing problem, and the burners for its consumption absorbed considerable attention then and have done so to this day.

The first complete gas works built was fundamentally the same as the coal-gas works of to-day. The coal was placed in retorts and the gas was taken off through hydraulic mains, passing through a scrubber, a condenser and a purifier of some character or other.

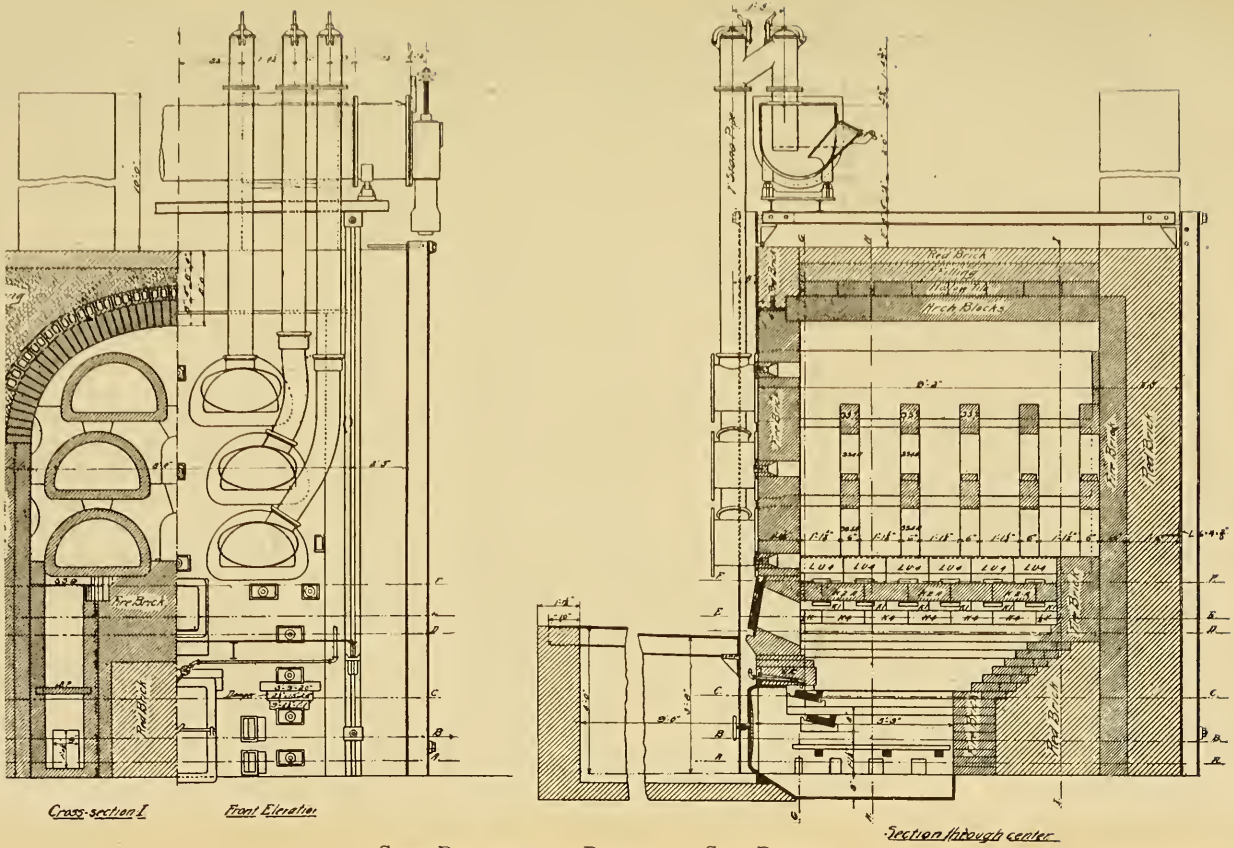
*Manuscript received October 13, 1903.—Secretary, Ass'n of Eng. Socs.

The storage holder caused considerable uneasiness when first erected, and the Common Council passed ordinances requiring that the "gasometer" should be inclosed in a substantial brick building, so that in case of an explosion the community would be protected from injury by the building. The honorable members of the Council were surprised and incredulous when informed that the contents of the gasometer could not explode until mixed with air, and they were dumbfounded when a pick point was driven through the side of the holder and a torch applied to the hole resulted in nothing more than the emission of a flame from the opening. Even to-day thousands of our citizens hold much these same beliefs.

COAL GAS.

The apparatus for the manufacture of coal gas consists of one or more benches, consisting of an arch or oven, constructed of fire-brick, at the bottom of which is a furnace, the upper part of the arch being filled with retorts made of clay with cast-iron mouthpieces. These mouthpieces extend beyond the brick wall which closes the end of the arch, and have lids which are readily removed. Attached to each mouthpiece is a cast-iron pipe for conducting the gas away from the retort. These riser pipes pass up to the top of the bench and down into what is known as the hydraulic main. This hydraulic main is in effect a water seal or valve, and gets its name from the fact that it is partially filled with water, which water rises up above the bottom of the gas or dip pipes passing down into the main. When the gas is being generated in the retort it forces its way up through the water. In doing so the water condenses a portion of the tar that is in the gas and the tar is drained off from the bottom of the hydraulic main. This water also absorbs a portion of the ammonia that is present in the gas as an impurity. The special purpose of this hydraulic main, however, is to automatically prevent the gas from going back from the holder into the retort, when the mouthpiece is open for the purpose of drawing the coke or charging the retorts with coal, acting much after the fashion of a check valve.

The pressure in the retorts necessary to force the gas through the water in the hydraulic main and the several pieces of purifying apparatus into the holder is so great that there is a considerable loss in the yield of gas, unless relieved by the introduction of a suction pump, known as an exhauster. This exhauster is usually connected up in the line of the main gas off-take pipe immediately beyond the retorts. The exhauster is so constructed and the supply so regulated that any desired pressure can be kept in the hydraulic mains



SEMI-RECUPERATOR BENCH OF SIX RETORTS.

at all times. After the gas has been drawn out by and has passed the exhauster it is put through a condenser for cooling, in which a great deal of the tarry globules or vapor is thrown down and drains off to the tar well. Then it usually passes through some further form of tar extractor or washer, where the remaining particles of tar should be removed. Thence it passes through the scrubber, where it is brought in contact with water, which absorbs the remaining portion of ammonia in the gas. After the gas has left the scrubber it should need but one more purification, and that is the removal of the sulphur compounds which usually appear in the form of sulphuretted hydrogen and bisulphide of carbon. These sulphur compounds were formerly removed by quicklime moistened and placed upon trays in large cast-iron boxes, the gas being forced through this lime. In later years the lime has been practically abandoned and replaced by what is known as "iron sponge," a preparation of some form of oxide of iron. This oxide of iron takes up the sulphuretted hydrogen, forming sulphide of iron. This sulphide of iron reoxidizes on being exposed to the air, depositing fine crystals of sulphur and reforming as oxide of iron, and can therefore be used over and over until it becomes excessively charged with sulphur.

A small percentage of free sulphur is very desirable for removing traces of bisulphide of carbon in gas, as the sulphur has a very decided affinity for bisulphide of carbon, and mechanically holds it behind.

These purifying materials were formerly regarded as excellent remedies for whooping cough, and many an old gas man will recall incidents of the hundreds of children he has treated for this complaint.

When the gas leaves the lime or oxide boxes, it is entirely purified and ready for use, if the work has been properly done. It is then passed through the station meter or mechanical accountant, which shows the amount of gas made, and is then stored in the holder, whence it is distributed through the mains, services and housepipes of the community to the burners where it is consumed.

In passing from the mains to the housepipes the gas once more is measured by a mechanical accountant; that is, by the usual house or consumer's meter.

The coal best adapted to the manufacture of coal gas is a bituminous coal, containing from 20 to 40 per cent. of volatile matter, rich in hydrocarbons, and is typified by the following analy-

sis of one of the best grades of Pittsburg gas coal, which shows as follows:

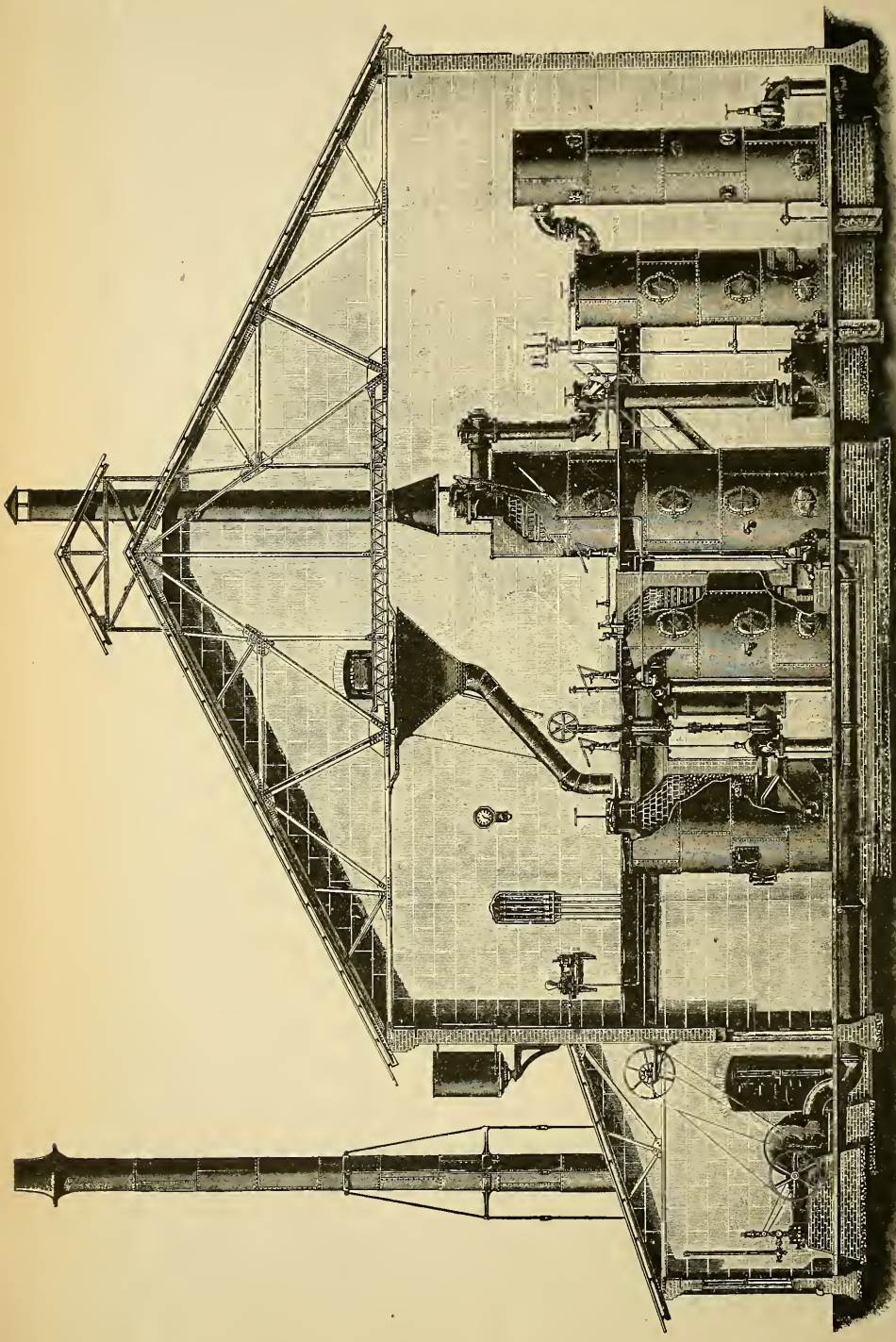
Moisture	1.26
Volatile matter	36.14
Fixed carbon	59.70
Ash	2.90
Sulphur	.99

In this analysis the sulphur was separately determined.

WATER GAS.

Professor T. S. C. Lowe was employed by the Federal Government, during the Civil War, in the balloon service of the army, and in his experiments to produce large quantities of hydrogen for use in balloons he invented, as the result of his experiments, what is commonly known as the "water-gas" process. This process is substantially the disintegration of steam by a bed of superheated carbon, producing carbonic oxide and hydrogen. The blue or non-illuminating gas thus produced possesses very inferior heating qualities, being only about 300 B. T. U. to the cubic foot, while illuminating gas possesses from 650 to 750 B. T. U. to the cubic foot; but when the vapors of oil are introduced, there is produced the commercial carburetted water gas of to-day.

The process of the manufacture of the water gas differs from that of the coal gas only in the method of generating. The water-gas apparatus consists of a generator, carburettor and superheater. The generator is a large vessel made of sheet steel, lined with fire brick with grate bars at the bottom. The carburettor is a similar shell lined with fire brick and filled with fire brick set loosely to form checker work. The superheater is also a steel shell, precisely similar to the carburettor, but longer, and is lined with fire brick and filled with checker brick, the same as the carburettor. These shells stand on end, each one close to the other. The generator is connected to the carburettor at the top by a pipe lined with fire brick. The carburettor is connected to the superheater at the bottom by a similar pipe lined with fire brick. On the top of the superheater is a large valve, known as the "stack valve," and leading out from the side of this stack valve is the off-take pipe, which passes down to a washer or seal, corresponding precisely to the hydraulic main or water valve in the coal-gas process. After the gas has passed this wash-box or seal, the purification process is precisely the same as in the case of coal gas. The method of manufacturing water gas is as follows: the generator is filled with coke or hard coal and ignited



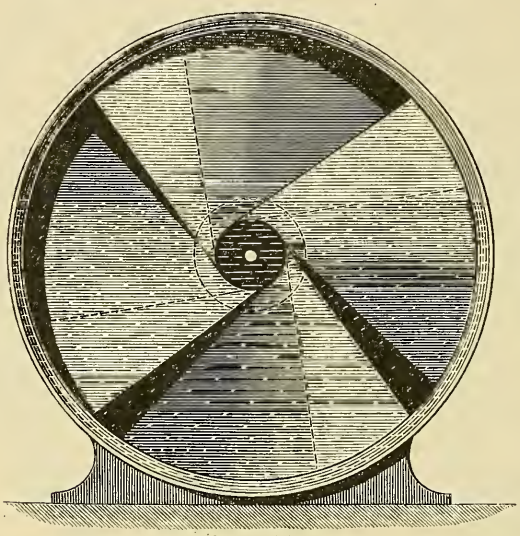
STANDARD DOUBLE SUPERHEATER LOWE WATER-GAS APPARATUS.

at the bottom. A fan or blower of proper size, operated by an engine, furnishes a blast which is controlled by a valve at the bottom of the generator. The blast being admitted under the grate bars, passes up through the fuel bed and brings up the heat of the coke or coal, at the same time making a producer gas which passes into the top of the carburettor, where another blast is admitted, igniting this producer gas, causing a secondary combustion that results in bringing up the temperature of the checker brick in the carburettor. Some of the producer gas passes down through the carburettor into the bottom of the superheater, where another blast is admitted, igniting this producer gas, causing further combustion and bringing up the temperature of the checker brick in the superheater. The "blow" is conducted for a time sufficient to bring up the temperature in the generator to from 1900 to 2000 degrees, and the checker brick of carburettor and superheater to a degree varying according to the quality and kind of oil to be used; at any rate, to a red heat. When this proper temperature has been obtained throughout the apparatus, the air blast is shut off, the stack or outlet valve on the superheater is closed and steam is admitted under the grate bars of the generator and passed up through the bed of superheated carbon and is thereby dissociated, the reaction in the incandescent coal or carbon producing hydrogen and carbonic oxide, that is, "water gas" commonly known as "blue gas." This water gas passes through the pipe connection into the carburettor, where it comes in contact with an oil spray from an injecting nozzle, which distributes oil at the top on the red-hot checker brick, and thus generates oil vapor, and this oil vapor, mingling with the water gas, passes down through the checker brick of the carburettor into the bottom of the superheater and up through the superheater, during which passage the oil vapor is changed to a fixed gas. The resulting oil-water gas is then passed out of the off-take pipe down through the washbox and out through the purifying apparatus to the holder. In the production of carburetted water gas no ammonia is made. In practice, the air blast is kept on from five to seven minutes, and this process is continued throughout the day, or week, or month, or year, the only interruptions being for coaling up, clinkering and repairing.

In the manufacture of water gas the fuel used is either coke or anthracite coal. No water-gas process has yet been successfully devised by which soft or bituminous coal can be used. Several of these processes have been attempted, and in a number of cases plants have been installed, but after being operated for a few years,

in most cases they have been converted into some standard form of water-gas apparatus.

In former days the demand for high candle power was the cause of the marketing of large quantities of cannel coal for gas making, and the gas was made by mixing a certain percentage of cannel coal in with the gas coal. After the introduction of the carburetted water gas, a great many plants abandoned the use of the cannel coal and installed auxiliary water-gas plants, making a rich water gas, to be mixed with coal gas, and thereby bringing up the candle power of the mixed gas to the desired standard.

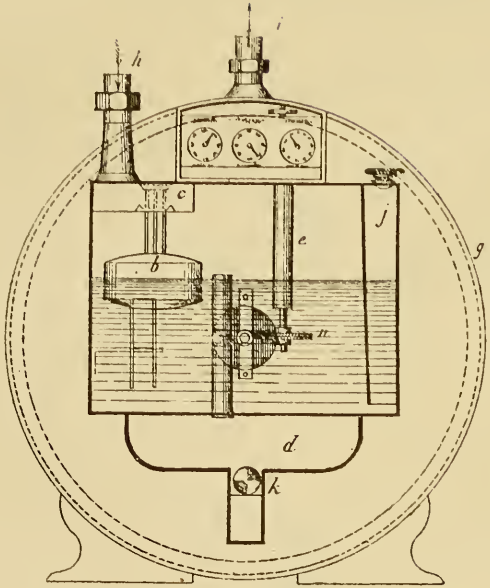


Wet Meter, Showing Drum from Outlet End.

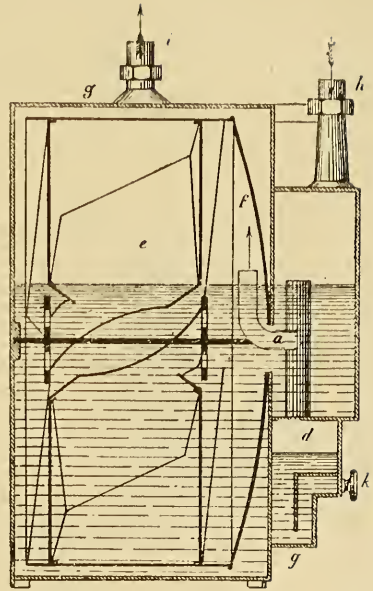
METERS.

One of the first gas meters invented was made of bladders, which were so arranged that one bladder would be filled with gas from the holder, and in expanding would force the gas out from another one already filled, and a valve system would shift the responsibility from one to the other, and thereby furnish a steady supply. This shifting of the valves by suitable clockwork registered the number of times each bladder had filled and emptied. In this way the amount of gas passed could be obtained. These bladders, owing to the properties of gas, soon became dried and cracked, and were finally abandoned for improved devices. The wet and dry meters were the final results of experiments on these lines.

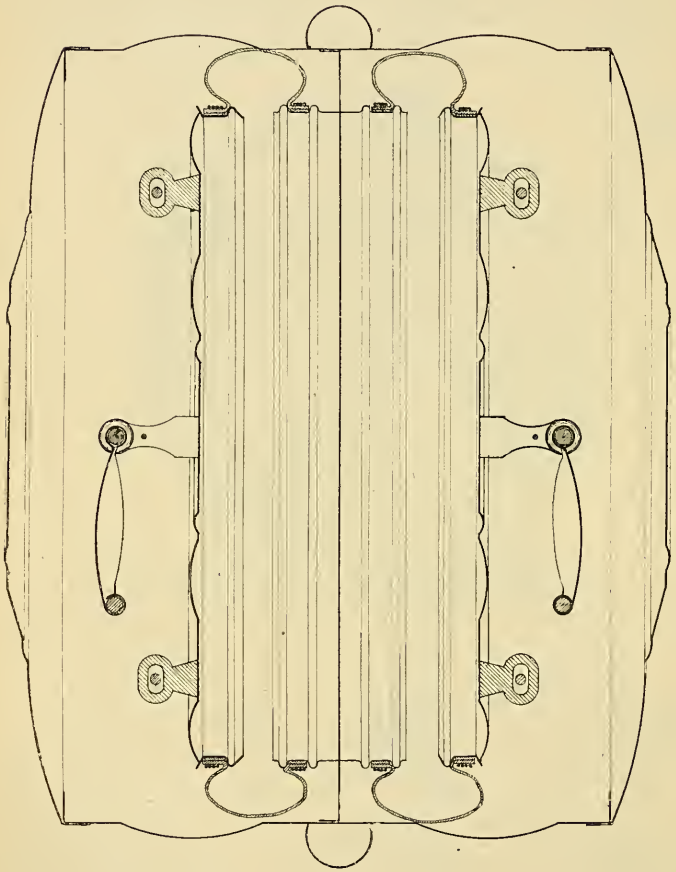
The wet meter consists of a miniature overshot water wheel partially submerged in water and revolving on a shaft. This wheel



Wet Meter, Showing Water-Level Float *b* and Gear Shaft *e* Connection to Dial.

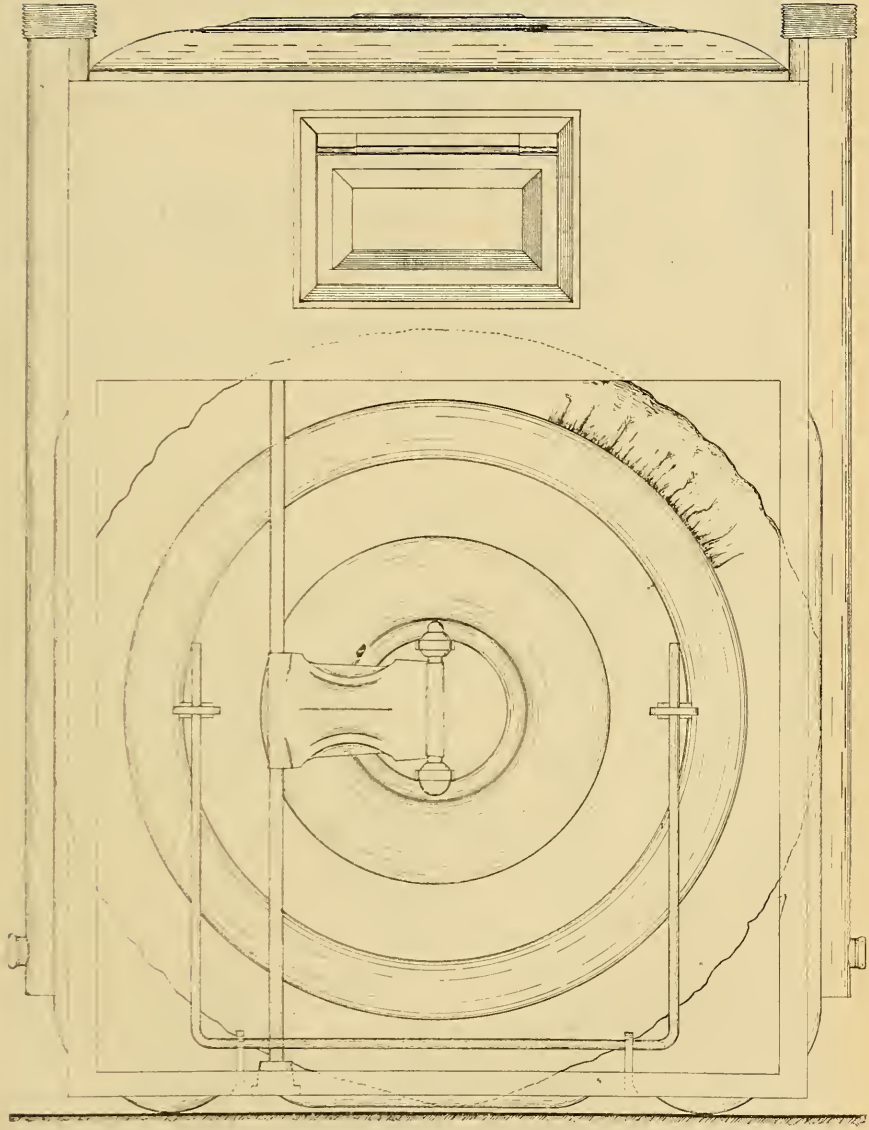


Section through Wet Meter, Showing Dry Well *a* Inlet for Gas.

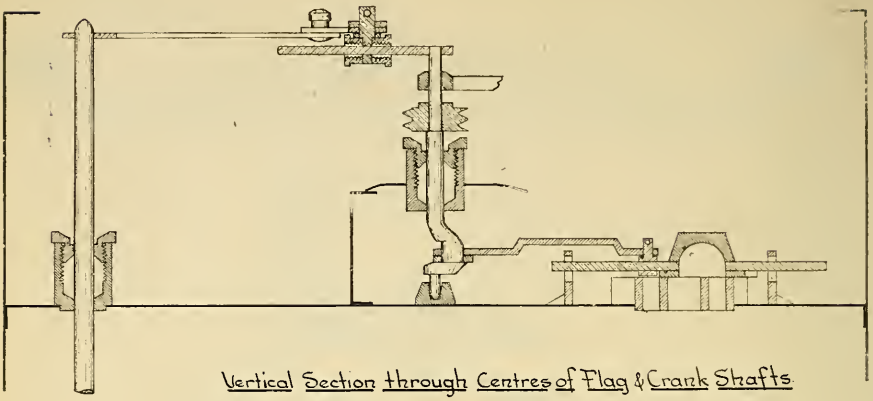


Horizontal Section through Centre of Diaphrams.

Dry Meter.

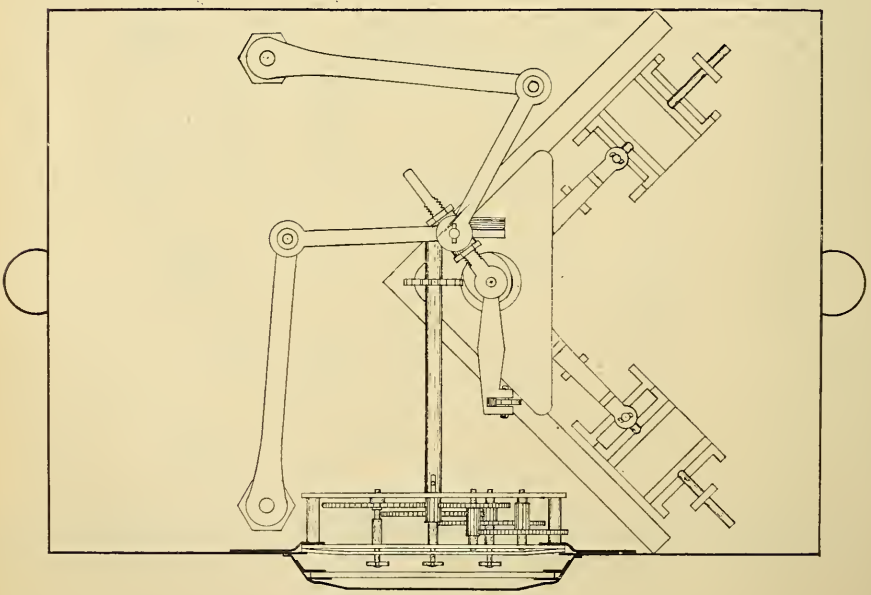


DRY METER, SHOWING DIAPHRAGMS AND LEATHERS.



Vertical Section through Centres of Flag & Crank Shafts.

DRY METER.



Plan View of Works.

DRY METER.

or drum is divided by partitions into buckets or chambers in such a way as to admit the gas into one of the partitions above the water. The pressure of the gas acting against the partition on one side and the water on the other causes it to revolve, and just before this section begins to shut off from the supply another section comes in and begins to take gas. Immediately after this, the first section shuts off the intake, and, being already filled with gas, begins to discharge the gas into the case which surrounds the drum. Given the exact cubical contents of these various chambers, the quantity of gas passed with one revolution of the drum can be ascertained, and properly constructed gear wheels, operated by a pinion on the main shaft, register the amount of gas that passes.

The dry meter operates through two side valves, and the working parts of the meter are two or more diaphragms attached to the valves by means of rocking shafts and link motion. The diaphragms are given freedom of movement by means of leathers attached to the diaphragms and to the partition between them, and the whole is inclosed in a case. As gas is admitted on both sides of the diaphragms, it is evident that movement of either diaphragm causes a flow of gas to the outlet of the meter. When one diaphragm is on the dead center, the other one is in full action, thereby producing a steady flow of gas. The links operate a crank shaft, and this crank shaft operates the valves and the registering gear. The area of the moving diaphragm, multiplied by its lineal travel, will give the cubical displacement, and the consequent flow of gas can be known for a given number of movements of the diaphragms. The diaphragm leathers are soaked in oil, and so long as they remain sound the registration of the meter will continue correct. The chief difficulty, however, is that these leathers in time become hard, and the constant movement of the diaphragm cracks them and a portion of the gas begins to pass through without registering.

Fully 90 per cent. of the dry meters that are wrong are found to be slow. One can readily see from the construction of the meter that in order to make the meter run fast the travel of the diaphragm must be reduced, but the limitations of the crank shaft require a certain amount of motion on the part of the diaphragm to pass the dead center, and if this is not met, the meter will refuse to operate.

BURNERS.

The original cock spur gas jet burning a 14 C. P. gas produced about 2 candles of light per cubic foot of gas consumed per hour, or on 5 feet per hour, which is the standard consumption per

hour and basis of all reference to candle power of gas, would produce 10 candles of light. As improvements were made the quality of gas was raised, and 18 candle gas with an ordinary gas jet produces from 3½ to 4 candles per foot of gas consumed per hour. The common Argand burner produces less than this. The Sugg Standard English Argand produces 4 to 4¼ candles per foot, and the Siemens and Lungren lamps increase this yield of light to about 10 candles of light per cubic foot of gas consumed per hour. The Welsbach light, when first put on the market, gave a fraction over 12 candles of light per foot of gas consumed per hour, while the Welsbach single burner of to-day gives something over 20 candles of light per cubic foot of gas consumed, and the inclosed incandescent gas lamp, known as the "gas arc," will give as high as 25 and sometimes 30 candles of light per cubic foot of gas consumed per hour.

NEW ORLEANS.

In 1829, on the 7th day of February, the Legislature of the State of Louisiana passed an act incorporating a company under the title of the New Orleans Gas Light Company. This franchise was declared forfeited in 1833, and the exclusive privilege of vending gas lights in the city was given to James H. Caldwell, of New Orleans. In 1835, by an act of the Legislature, Mr. Caldwell transferred his privileges to the New Orleans Gas Light and Banking Company. The banking rights of the company were later relinquished. In 1881 an opposition company was projected, and, as a result of four years' litigation, the Supreme Court of the United States, in 1885, confirmed the exclusive rights of the present company, as granted by its charter, to make and vend gas lights until April 1, 1925.

One of the provisions of the grant was that the price of gas should never be raised above $6 per 1000 cubic feet. In 1854 there was another amendment to the charter, which provided that the price of gas should not be above $4.50 per 1000 cubic feet.

The first plant was erected in 1836, and consisted of three benches, of three iron retorts each, on the corner of Gravier and Locust Streets (now known as Robertson Street). The plant was enlarged about 1850 or 1852 to sixteen benches of three iron retorts each.

In 1859 the building that is now used as a generator room was erected, and in it were installed forty benches of three clay retorts each, each retort being 12 x 20 inches and 8 feet 16 inches long. The hydraulic main was circular in section, 18 inches in diameter, and the benches were supplied with 4-inch stand pipes. About 1868

there were placed in these benches five retorts, space for them being created by lowering the floor line of the retort house and setting the furnace lower down. The same hydraulic mains were adapted to this change.

These benches were used until the consumption had reached 1,100.000 cubic feet per day, and about 1875, the retort house, on the corner of Perdido and Magnolia Streets, was built, and in it was installed forty-eight benches of six retorts each. These benches made all the gas until about 1883, when the Egerton process for making gas was put in.

This process consists of a set of generators for producing water gas and an evaporator for vaporizing naphtha. The naphtha vapor was taken up by the water gas and carried along through heated retorts as fixing chambers. This was the time the "dollar-and-cent meter" was put into use in New Orleans, and 33 candle gas was made. Many of these dollar-and-cent meters are still in use in the city. The rate on these meters is $3.70 per 1000, and, in order to reduce the registration of the dollar-and-cent meter to cubic feet, it should be divided by 3.7. This, or a similar water-gas process, was used until 1895, when a standard Lowe water-gas plant was installed and has since been in continuous operation.

I have already referred to the mechanical accountant—the station meter. All of the gas made is measured by this station meter, and, at the close of a month's business, all gas registered by the consumers' meters is totaled up, and the difference between the amount made and the amount sold is ascertained. This amount will vary in different plants, and is largely dependent upon a variety of conditions, viz: the temperature at which the gas is measured in the station meter, the tightness of the mains and the correctness of the consumers' meters.

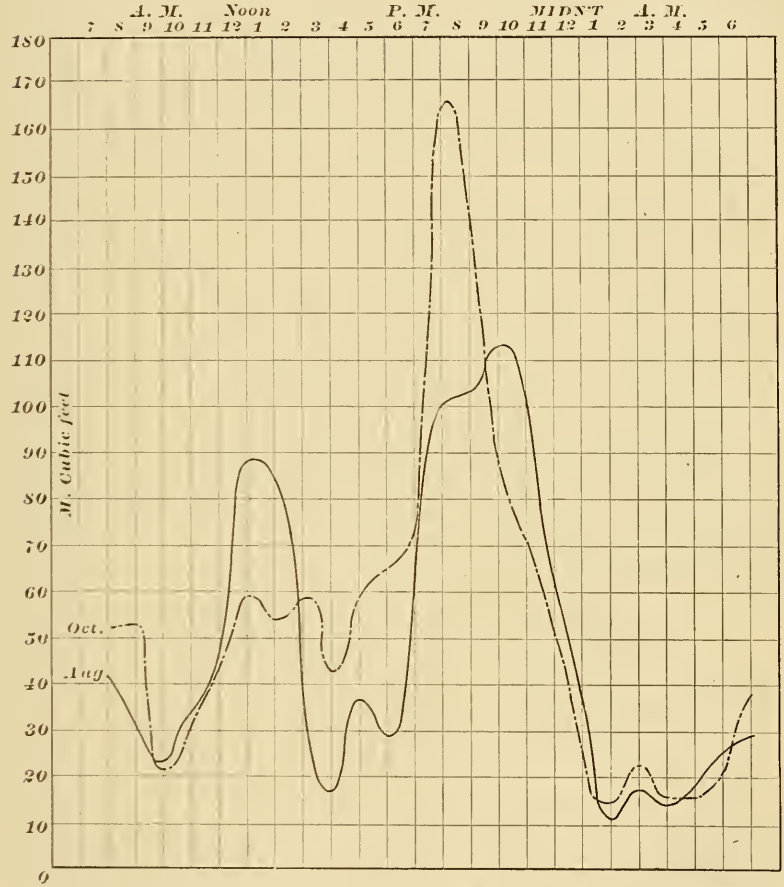
To overcome the question of temperature the quantity of gas measured by the meter is corrected to a uniform temperature, say 60 or 70 degrees, according to the climate in which the business is being conducted. Notwithstanding this fact, it is never found, at the end of the year, that all of the gas sent out into the mains has been sold, and, if the loss is no greater than 8 per cent., it is concluded that mains and meters are in excellent condition; but cases are on record where the loss has been as great as 25 per cent., and even a few instances where it has reached 50 per cent., in the early days when wooden mains were considered the very thing.

In New Orleans the question of leakage has not been very serious, because of the presence of water in the ground at practi-

cally all times of the year. We have little trouble over the loss of gas from its getting out of the mains, because where there is a leak in the main there is water enough present in the ground, with sufficient pressure to prevent the gas from leaking out; instead, the water leaks in, and, as a result, we have a large expense account for pumping water out of the mains. If the ground became well drained and the usual conditions of elevated land existed, no doubt our leakage account would be as large as other well-regulated plants. This seepage of water into the mains gradually causes the formation of a deposit, which finally has to be removed. This process of washing out the gas mains is, I believe, peculiar to New Orleans. The mains are flushed in this manner: The main and branches of two or three blocks are cut and plugged, and a hose is attached from a fire hydrant to the main; the main is filled with water under pressure, and the plug at the far end is knocked out and the water allowed to gush through, after which it is washed for eighteen or twenty minutes, and thereby the mass of sediment at the bottom of the mains is removed. This accumulation has become so great in some instances that it has retarded the flow of gas during the early hours of the evenings to such an extent that certain sections have been entirely without gas.

In the distribution of gas from the holders, all of the pressure of gas in the mains is given by the weight of the holder. In order to maintain uniform pressure and not to have a presssure on the mains higher than is necessary to give a good service, governors of the pressure are used at the works. These are operated in a manner to produce a pressure according to the demand on the mains, but in the rapid development of the gas business recently experienced in New Orleans, the demand on the mains was far greater than the supply of gas that could be forced through them with the weight of the holders, and even had they been heavy enough, it would have been undesirable, because the pressure would have been excessive to the extreme in the pipes leading out from the works, and would have gradually diminished until out or near the extreme limits of the system, and the proper pressure would not be obtained. In order to overcome this difficulty promptly, and at a reasonable cost, a high-pressure system of distribution was introduced in New Orleans, and has been in operation for about a year past. This system consists in compressing the gas to from 15 to 35 pounds, and sending it out to the outlying districts in small wrought-iron mains, laid expressly for the purpose, to a desired point where the gas is fed into the low-pressure mains and the pressure is re-

duced through a regulator to the proper amount to be maintained in the low-pressure mains. At the present time there are four such stations in the city. The entire gas supply of Algiers is furnished through a high-pressure pipe, which is laid on the bed of the Mississippi River, and the low-pressure distribution pipes in Algiers are



Curve Showing Hourly Output for One Day Each in October and August.

supplied with gas through a small governor station on the Algiers side of the river. So far, this method of distribution of gas has proved eminently satisfactory, and the gas supply of Algiers has been interrupted on but two occasions in the six months since it was turned on. This was necessitated by the breaking of a fitting in the high-pressure piping at the governor station in Algiers, and the change of fittings was accomplished in less than an hour. The

other shut-off was occasioned by the necessity of lowering the main on this side of the river at the head of Julia Street, and, in order to keep the supply of gas on while this lowering process was going on, a heavy 2-inch steam hose was inserted in the pipe in order to give a flexible connection to permit the pipe to descend, keeping the gas on all the time. This 2-inch rubber hose is still doing business in the turbid flood that has been rushing by for several weeks past, but no interruption of the supply has occurred.

The old Valence Street Works, formerly the Jefferson City Works, have long since been abandoned for manufacturing, and only the storage holders at this plant are in use. These holders are filled daily from the high-pressure main which was carried there for that purpose.

The hourly consumption of gas is subject to quite a large variation during the twenty-four hours, and there is a distinct peak of load as in the electric consumption for electric light. The accompanying diagram shows this peak.

The history of the gas business in New Orleans is almost the history of the gas business in the United States. It was the second gas works built in this country. To-day the gas of New Orleans is made with the most modern apparatus known, and if it is safe to predict from the past, New Orleans will be one of the first to avail itself of any material improvements which may be made in the manufacture of gas.

GOOD ROADS.

By George C. Diehl, Member Engineers' Society of Western New York.

[Read before the Society, April 7, 1903.*]

Mr. President and Gentlemen:—The public press has wisely published very complete reports of the various good-roads speeches, meetings, conventions and legislative enactments; and doubtless I can but repeat facts familiar to you.

It is the duty of every member of this Society, when called upon by the Secretary, to address the members on the subjects with which he is familiar, from his experience as an engineer; and from that standpoint I will state some ideas concerning good roads which have come to my notice in an official capacity, while employed by the State Engineer's Department and by the Board of Supervisors as County Engineer. I must confess I had never given much thought to good roads or bad roads before I was paid for doing so.

This was a mistake, and I believe it the duty of every patriotic citizen to inform himself and lend his aid to every worthy improvement of the commonwealth and the municipality. Especially is this true of every engineer, on such great subjects of the State's internal improvement as the construction of a 1000-ton barge canal and the improvement of the public highways; for these public problems could be more quickly solved and the apparently insurmountable obstacles overcome should the engineers of the State devote some of their time, energy and ability to this patriotic duty.

It is only since the early nineties that the improvement of the public highways has been systematically carried on and public opinion sufficiently aroused to the necessity of action by our various legislative bodies.

A history of the good-roads movement, previous to the nineties, would chronicle the persistent efforts of a few pioneers, meeting with little encouragement, working without system, but steadfastly sticking to their task and making possible this great internal improvement by enlightening the public mind to the necessities for the betterment of transportation facilities to the great avenues of commerce—the railroads and the waterways.

Four methods of improvement of highways suggest themselves to me: (1) with National aid; (2) with State aid; (3) by the county; (4) by the town or locality.

For a number of years the National Department of Agriculture

*Manuscript received November 11, 1903.—Secretary, Ass'n of Eng. Socs.

has had a Good-Roads Department, which has made valuable studies in geology, petrology, character of soils and various natural conditions, has built short experimental sections of road illustrative of the various types of roadways, and more recently this Department has operated the so-called "good-roads trains," equipped with modern stone crushers, rollers, road machines, etc. These trains have been sent through the Southern and Western States, where the good-roads movements are not so far advanced, and have stopped about a week in each locality and built a section of sample road, inviting everyone and educating them along the most improved lines of road building.

A bill has recently been introduced into the National Congress by W. P. Brownlow, which provides for a system of National, State and local co-operation in the permanent improvement of the public highways. This bill contemplates an appropriation of $20,000,000, which shall be apportioned amongst the various States in proportion to their populations, the Government to pay one-half and the State and locality one-half of total cost of road. It is also provided that a bureau shall be created under the direction and management of the Secretary of Agriculture, consisting of a director, at $4500 per annum; four field experts, at $2000 per annum; four civil engineers, at $1800 per annum; four road experts, at $1400 per annum, and others. The remaining features of the bill are similar to the Higby-Armstrong Bill of this State, of which mention will be made later.

In the improvement of highways with State aid, I believe the States of Massachusetts and New Jersey were the pioneers. The system adopted by the former State is regarded by many to be drawn along the most advanced lines. The States of Connecticut, Maryland and others have added greatly to the public store of knowledge. The work in Massachusetts, both in construction and maintenance, is done under the direction of a commission of three, appointed by the Governor, for a term of five years, terms expiring separately, so that always two experienced members remain on commission. However, time will not permit me to go into detail of work done in other States.

On March 24, 1898, the so-called Higby-Armstrong Good-Roads Bill became a law in New York State. This law, in a general way, provides that the owners of a majority of lineal feet fronting on any public highway may present to the Board of Supervisors a petition, setting forth that they desire such highway improved under the provisions of this act. The Board of Supervisors must pass a

resolution (or, if no petition has been circulated, may pass a resolution) that the public interest demands said improvement. A certified copy of this resolution is sent to the State Engineer, who investigates and determines if the section of road is of sufficient public importance to come within the provisions of this act, taking into account the use, location and value of such highway for the purposes of common traffic and travel. Should the State Engineer approve of such resolution, he shall cause the road to be surveyed and mapped and plans and estimates of cost of improvements made; the macadam portion of the road to be 8 to 16 feet in width, unless for special reasons given by the State Engineer it is required to be of greater width. He shall then submit to the Board of Supervisors estimate and certified copy of plans. The Board of Supervisors may, by a majority vote, adopt a resolution that such road be improved. The State Engineer then advertises for bids for said improvement and awards the contract, which must be at a price less than his estimate, but may, in his discretion, be awarded to the Board of Supervisors, even though not the lowest bidder. Fifty per cent. of the expense of construction shall be paid by the State and 50 per cent. by the county in the first instance; of which latter 50 per cent. 35 per cent. of the total cost of construction shall be a general county charge, and 15 per cent. shall be charged to the town in which the road is built, if without petition; or to the abutting property owners, if built by their petition.

The improvement of such highways shall be taken up in the order in which the State Engineer shall receive the resolutions of the Board of Supervisors, which approve of the plans and estimate. The property owners shall thereafter pay all highway taxes assessed against them in money. The bill also provides for collecting statistics, consultation by highway officers, annual report to Legislature, that the road shall be maintained thereafter as a county road, and that the Commissioner of Highways shall care for same as directed by the State Engineer.

The appropriations which have been made by the State and counties under this law are as follows:

	State.	Counties.
1898	$50,000	$63,872
1899	50,000	42,876
1900	150,000	431,227
1901	420,000	1,055,874
1902	795,000	1,748,115
	$1,465,000	$3,341,964

Forty-six different counties have petitioned for State aid, and the totals for the State are as follows:

Mileage petitioned for to January 1, 1903	2415
Mileage plans approved by counties	825
Mileage completed	186
Mileage in process of improvement	167

In Erie County—

The total mileage of roads outside of Buffalo and incorporated villages is	1900
Mileage petitioned for to January 1, 1903	77
Mileage plans approved by county to January 1, 1903	53
Mileage completed	12
Mileage in process of improvement	20

This law is applicable only to the main market roads in the State. The total mileage of roads in New York State, exclusive of cities and incorporated villages, is approximately 73,800. Approximately 10 per cent. of this mileage can be improved under this law, or about 7500 miles, at $8000 per mile, a total cost of about $60,000,000. If the State should appropriate $1,000,000 a year, this improvement would take at least thirty years, and it is for that reason that the good-roads advocates are urging the Legislature to approve of a $50,000,000 bond issue for the improvement of roads that the commonwealth might derive the benefit of these improved highways at an early date, and that produce might also be brought to main shipping centers from points now well-nigh inaccessible.

The total acreage of farms in New York State, according to the United States Census, was: 21,961,562 acres in 1890 and 22,648,109 acres in 1900, an increase of 686,547 acres.

The value of farm lands, fences and buildings was: $968,127,286 in 1890 and $888,134,190 in 1900, a decrease of $79,993,096 in ten years.

In 1890 New York State ranked third in agriculture.

In 1900 New York State ranked fourth in agriculture.

The advocates of a large bond issue for good roads contend, and I think rightly, that improved highways will increase farm values just as trolley lines have created values in cities and suburban localities, and that improved transportation facilities are an absolute necessity, if the commercial supremacy is to be maintained.

The General Highway Law also provides that for the county road system, under the provisions of this enactment, the Board of Supervisors may, by a majority vote, designate the leading market roads lying outside of the limits of a city, and cause such designation

and a map of such roads to be filed in the County Clerk's office. Such roads may then be improved, repaired and maintained as a county charge, under the direction of the Board of Supervisors and a County Engineer.

As before stated, the Higby-Armstrong Law applies to only about 7500 miles. There remain approximately 66,300 miles of road which must be improved under some other system.

To appreciate this vast mileage of roads to be improved, I cite from the New Jersey Good-Roads Report for 1902:

THE TOTAL MILES OF PAVEMENT OF ALL KINDS IN THE UNITED STATES.

Cobblestone	1,000
Granite and Belgian block	3,500
Brick	2,000
Wooden block	1,500
Asphalt	3,500
Gravel	4,500
Macadam	4,000
Total	20,000

There is now on the statute books an enactment known as "The Fuller Law," which, in a general way, provides that any town may adopt a cash system of collecting highway taxes, and thereafter for each dollar collected the State will pay to such town 50 cents; not, however, to exceed one-tenth of 1 per cent. of the assessed valuation of said town. It is also provided that the town must make the present labor tax payable in money in a minimum of at least 50 cents on a dollar of the present commutation rates.

The total assessed valuation in the State, exclusive of incorporated cities and villages, is approximately $360,000,000. Thus the annual payment by the State would not exceed about $360,000. The present method of road improvement (in the majority of towns) is by day-labor, under the direction of highway commissioners, who appoint overseers in the various highway districts. This antiquated system of road improvement is a relic of the ancient English law, which became our law after the Revolutionary War.

There are about 1000 highway commissioners, 50,000 overseers and an annual expenditure of $2,000,000 day-labor. Each mile has a different overseer and a different system, and much unnecessary work, and more well-intended but absolutely useless work, is done. At $1.50 for each day's labor there is spent $3,000,000 per annum, so that in twenty years approximately $60,000,000 has been spent. How little there is to show for this vast expenditure, anyone who drives in the country can tell.

Should the entire State adopt the Fuller system the 1000 high-

way commissioners would have at least $1,500,000 annually to spend on the roads. Many of these highway commissioners know little of road improvement, having had no experience, although well meaning, and under competent superintendence probably would be efficient. And it is provided by Act, Chapter 396, of the Laws of 1902, that each county may appoint a County Engineer, who may be consulted by the highway commissioners and who may establish grades, indicate methods of drainage and improvement, etc., and, in short, superintend and direct all the work done by the highway commissioners.

The benefits derived under the Fuller Law up to January 1, 1903, are as follows:

	No. of Counties Benefited.	No. of Towns Benefited.	Amount of State Aid.
1898.....	8	43	$34,517
1899.....	14	75	54,057
1900.....	21	100	67,655
1901.....	24	139	102,509
1902.....	40	258	246,000 (approx.)

The question of wide tires, which I will but briefly mention, is one most vital to the maintenance of improved highways. In this country the narrow tire is in general use, although many tests have been made fully demonstrating the claims in favor of wide tires, less draft required, maintenance of roads in better condition, etc.

I have recommended to the Board of Supervisors, at various times, the adoption of a "wide-tire" law, but none has yet been adopted. In Europe narrow tires have long since been discarded, and every wagon is a road maker. Tires vary from 3 to 10 inches in width, and rear axles are longer than fore axles, so that wheels do not run in same track. The width of tires is determined in various ways, usually differing in various localities; but all achieve practically the same result. Some localities allow 550 pounds per inch width of tire.

The resolutions introduced in the Erie County Board of Supervisors provide that all wagons built to carry 1500 pounds or more, equipped with thimble-skein axle of 3 inches diameter or less, or steel axles of $1\frac{5}{8}$ inches diameter or less, or tubular axles of $2\frac{3}{8}$ inches diameter or less shall have a tire not less than 3 inches in width. With the corresponding types of axles, $3\frac{1}{4}$ inches, $1\frac{3}{4}$ inches, $2\frac{5}{8}$ inches in diameter, respectively, they shall have a tire not less than $3\frac{1}{2}$ inches in width. With corresponding axles, $3\frac{1}{2}$ inches, $1\frac{7}{8}$ inches, $2\frac{7}{8}$ inches or more, respectively, they shall have tires not less than 4 inches in width. The resolution made other provisions.

Briefly, the work that has been done with State aid, under the Higby-Armstrong Law in Erie County, is as follows:

The first road improved in this county was the Whites Corners Road, extending from the southerly city line, southerly to the village of Hamburg; built, 1898, 1899, 1900; length, 6.54 miles; total cost, $30,928; width of macadam, 12 feet; thickness, 6 inches; material, local limestone. The subsoil is a clay, with some quicksand. The road was more or less a failure, and a second contract was made to resurface the road with 2 inches of trap-rock, and widen to 20 feet that portion from city line to Limestone Hill (about ½ mile) and to place drain tile in soft spots. The total cost of second contract was $24,294. Present condition: south end, good; north end, poor; due, in my judgment, to macadam being too thin.

The next roads built were:

The River Road. Extends from the northerly city line at Niagara Street, northerly; built, 1900; length, 1.46 miles. Total cost, $17,000; width of macadam, 20 feet; thickness, 6 inches of macadam, 4 inches of gravel. Material, top 2 inches trap-rock, remainder local stone; condition, good.

The Orchard Park Road, Section No. 1. Extends from village of Orchard Park, northwesterly toward Buffalo; built, 1900. Length, 1.12 miles; width of macadam, 16 feet; thickness, 6 inches; material, top 2 inches trap-rock, remainder local stone. Condition, good. Total cost, $14,619.

Main Street Road, Section No. 1. Extends northeasterly from Main Street city line. Built, 1902. Length, 3.42 miles. Contract price, $25,000; width of macadam, 16 feet; thickness, 6 inches. Material, local limestone from Almshouse quarry. Condition, good.

There are now in process of construction the following roads:

Main Street, Section No. 2. Extends easterly from Williamsville to Transit Road. Length, 1.93 miles. Contract price, $15,100.

Transit Road, Section No. 1. Extends northerly from Main Street Road. Length, 4.28 miles. Contract price, $35,400.

Transit Road, Section No. 2. Extends northerly from Transit Road, Section No. 1, to north line of Erie County. Length, 4.06 miles. Contract price, $37,700.

Orchard Park Road, Sections 2, 3 and 4. Extends from Orchard Park Road, Section No. 1, to the Seneca Street city line. Length, 5.53 miles. Contract price, $79,300.

Big Tree Road. Extends from East Aurora easterly to Wales Center. Length, 4.00 miles. Contract price, $38,637.

There will probably be built this year:

Main Street Road, Sections 3 and 4. Extends from Main Street Road, Section 2, to easterly county line. Length, 12.20 miles. Estimated cost, $77,900.

River Road, Sections 2 and 3. Extends from River Road, Section No. 1, to village of Tonawanda. Length, 3.02 miles. Estimated cost, $26,400.

Aurora-Buffalo Road, Section No. 1. Extends from Seneca Street city line to town of Elma. Length, 5.57 miles. Estimated cost, $56,000.

I must apologize to you for discussing this subject more from the viewpoint of a layman than of an engineer, but unfortunately I had not sufficient time since my notification by the Secretary to prepare a paper along engineering lines. I would be pleased, however, to answer any questions that I can, and at some subsequent meeting, when a paper is wanted to fill in, I would gladly give what few ideas have come to me in my limited experience about surveys, plans, drainage, various road metals, character and treatment of subsoils, maintenance, stone-crushing plants and others.

CONCRETE-METAL CONSTRUCTION.

By Emile Villet, C.E., Member Technical Society of the Pacific Coast.

[Read before the Society, March 6, 1903.*]

In the hope that I may have the pleasure of imparting some new feature in the art of armored cement construction, as executed in foreign lands, I present these few pages, which refer to work performed, existing, and resisting the elements, and to work projected and under actual study; to wit:

(1) The wharf constructed at the port of Novorossisk, in Russia, on the Black Sea.

(2) The plan of wharf and wharf superstructure, entirely of cement and iron, drawn for the Department of Docks of New York city.

(3) A proposed plan of sea-wall construction, also entirely of cement and iron, made for the Board of Harbor Commissioners of San Francisco.

DESCRIPTION OF THE ARMORED CONCRETE WHARF AT NOVOROSSISK.

In 1896, Novorossisk having become an oil shipping point on the Black Sea, by reason of its geographical position with regard to the recently opened Trans-Caspian Railroad, now running through the oil regions of Southern Russia, a wharf of the ordinary wood-pile system was constructed to accommodate the steamships of 4000 to 5000 tons, about to engage in the petroleum carrying trade. This structure, attacked to some extent by the teredo, was partially destroyed by the fouling of a steamship and by the force of the rough seas which prevail during stormy weather in the Black Sea.

After the accident I was called to Novorossisk from the city of Kertch, where, during four years prior, I had constructed the sewer system, reservoirs, bridges, coal bunkers, etc., all of armored concrete, in order to reconstruct, in armored concrete, for the account of the owners, the portion of the wharf which had been destroyed.

The destroyed portion was built in two parts:

(1) The wharf proper, 70 feet long and 52 feet 6 inches wide.

(2) A footbridge, 37 feet 6 inches long and 19 feet 6 inches wide, connecting the remaining pile wharf to the new portion above mentioned.

These two portions give a floor area of 3724 square feet.

*Manuscript received September 8, 1903.—Secretary, Ass'n of Eng. Socs.

The floor, constructed of armored concrete 4 inches in thickness, is supported by twenty-four piles, $15\frac{3}{4}$ x $15\frac{3}{4}$ inches, joined together by stringers, $15\frac{3}{4}$ x $25\frac{3}{8}$ inches, forming spans 16 feet $4\frac{3}{4}$ inches from axis to axis. In each span these stringers are joined by five small beams, $7\frac{7}{8}$ x $11\frac{13}{16}$ inches.

By the terms of the contract, the structure must bear a test of a permanent weight of 213 pounds per square foot. The following is a copy of the test certificate, with accompanying diagram:

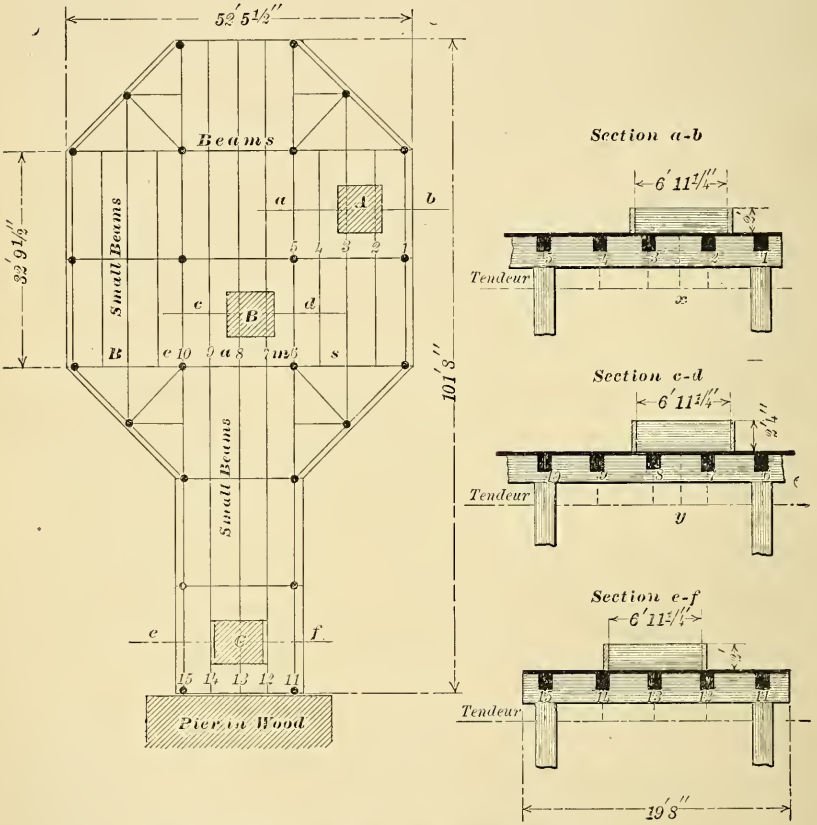


FIG. 1. PLAN OF PIER AT NOVOROSSISK, RUSSIA.

"Certificates as to the tests made of the part of the wharf built on piles with stringers, small beams and flooring, all of reinforced concrete, in accordance with the Russian Standard, at Novorossisk, Russia.

"On the 27th and 28th of May, in the presence of Mr. Maklarene, engine builder, and Mr. Freichist, engineer for bridges and roads, both residing at Novorossisk, resistance tests were made of the

wharf built of reinforced concrete by Mr. Emile Villet, C. E., and contractor of Novorossisk.

"According to the conditions prescribed by the contract of the 5th of June, 1900, the flooring must be capable of supporting a load of 213 English pounds per square foot.

"In order to make the tests bear on some weak points of the flooring, the points indicated by the letters A, B and C have been designated.

"The bays, submitted to the tests, rest on piles $15\frac{5}{8}$ x $15\frac{5}{8}$ inches, spaced 16 feet $4\frac{3}{4}$ inches from axis to axis; at each point the load affected a surface of 41 feet $5\frac{7}{16}$ inches.

"In order to measure the deflections, hangers were placed below the floor, and the distances from the hangers to the small beams (numbered from one to fifteen) and from the points z and y were taken and exactly noted.

"On the 27th of May, at 10 o'clock A.M., the boxes A and C were filled with gravel up to a height of 2 feet. Box B was filled with sand up to a height of 2 feet 4 inches. The given dimensions multiplied by the specific weight of the gravel and sand gave exactly a load of 213 English pounds per square foot.

"After the termination of the test, the flooring showed no deflection; twenty-four hours later, that is to say on the 28th of May, the flooring showed no deflection.

"Novorossisk, May 29, 1902.

"(Signed) MAKLARENE, FREICHIST."

The piles are square, $15\frac{3}{4}$ x $15\frac{3}{4}$ inches and 42 feet long, giving a cubic measurement of 2.7 cubic yards, which, at the density of 2.5 for the armored concrete, gives a total weight of 11,025 pounds, or 262 pounds per linear foot.

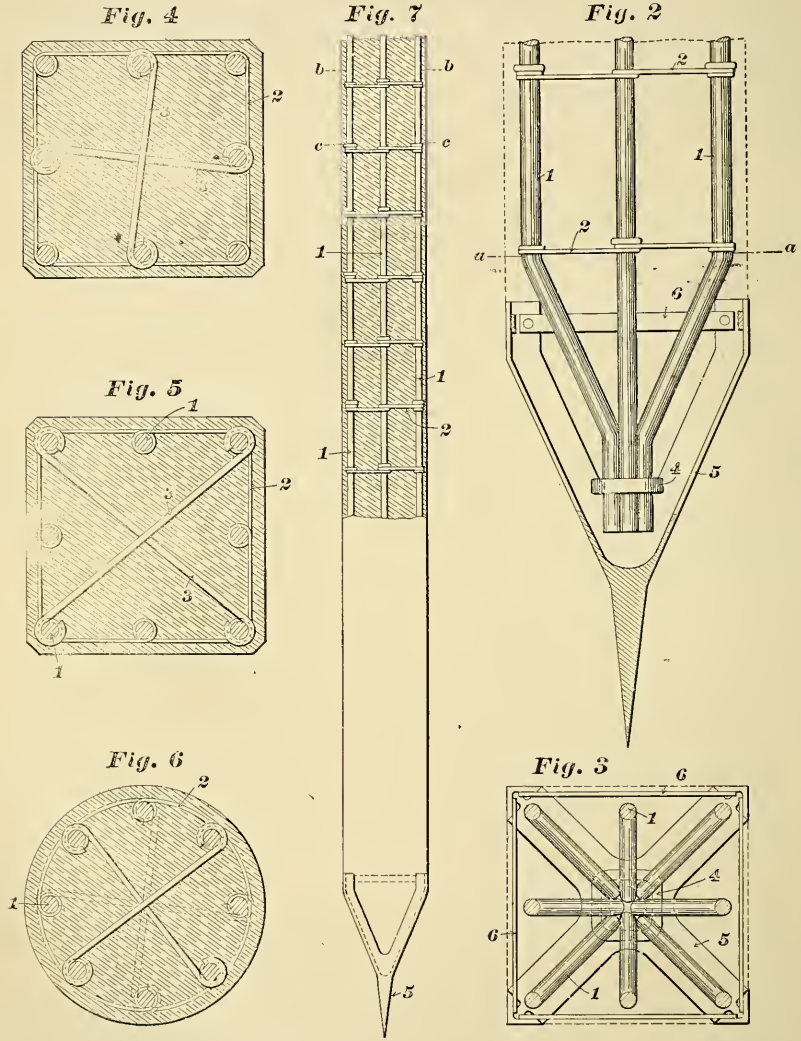
Each pile, having to support a floor surface of 269 square feet, should resist satisfactorily a compression of 85,584 pounds thus distributed:

Live weight, 269 square feet x 213 pounds	57,297	pounds.
Dead weight, floor, 269 x 52 feet	13,624	"
Stringers	6,615	"
Small beams	8,048	"
	85,584	"
to which add		
Coefficient of security 50 per cent. on live load of 57,297	28,649	"
Total	114,233	"

It is to be noted that the compressive strength is asked only of the iron composing the frame of the pile, and that the resistance

offered by the cement is not taken into account, the latter being considered as fulfilling simply the rôle of protector of the iron against the action of the salt water of the sea.

The iron frame of the pile is composed of eight bars of round iron, which are bound together every 10 inches by bands and by



ties, the latter diagonally joining the corner bars or the middle bars alternately, as shown in Figs. 4 and 5, on drawings accompanying patent.

The object of these ties, placed in the center of the body of the concrete, is to prevent the splitting of the central part under

the action of the pile-driving hammer. The quantity of iron for each linear foot of pile is 45 pounds.

Regarding the composition of the concrete for the construction of piles, gravel cannot be used because of its imperfect union with the cement to withstand the effect of the blows of the pile driver; only siliceous or quartzose sand, perfectly cleaned, can be used, and the cement, united with it and properly rammed, forms, with the sand, a homogeneous and solid monolith.

For a pile 42 feet long there are used: Sand, 2400 cubic yards. Cement, 3800 pounds. Water, quantity to be determined according to the quality of cement to be employed. In all other parts mixtures are made with quartz gravel, sand and cement.

Russian cement was used at Novorossisk, sand as above and the sea water of the Black Sea for mixing purposes.

The piles are constructed horizontally, and, after the removal of the mold in which they were formed, they are exposed to the atmosphere for several days, at the expiration of which they are immersed in water, where the process of solidification is completed. The duration of the immersion depends upon the nature of the cement used.

Thus any desired number of piles may be constructed at or near the projected wharf before the work of construction is commenced.

Fig. 2 shows the mode of construction of the iron frame at its penetrating part. (See drawings on patent.)

The pile driving is accomplished in the ordinary manner. After dropping the pile into position from a height of about 14 feet, which drop has shown a penetration of an average of 1 foot 6 inches into the hard calcareous bottom of the harbor of Novorossisk, the hammer, weighing 3375 pounds, is dropped from a height of 12 to 14 feet upon the head of the pile, striking an average of twelve blows and until the penetration has reached, on an average, 2 feet.

The piles are constructed of a length greater by 6 feet than the depth of the soundings actually shown, so as to admit of cutting the heads of the piles to a uniform level, and removing such portion of the piles, close to the head, which becomes splintered by the action of the hammer, notwithstanding the use of a cushion of wood placed on the head of the pile.

In leveling the heads of the piles the cement work only is removed and the protruding bars of the iron frame are then bent over and become locked with the armored concrete stringer, which

is constructed from pile to pile and forms, with the stringers, a homogeneous mass, thus preventing all shearing and torsion.

The beams and braces are made of prisms of a rectangular or square section; and the iron frames, forming ties or tie rods, are placed in their interior.

These frames and the body of the cement are calculated to resist deflection (compression), rupture (tension) and shear.

These beams and braces may be constructed in long spans.

In the construction of wharves, the rôle of the braces is to localize, at a certain point in the height of the piles, the lateral effects to which the wharves are subjected by the fouling of vessels,

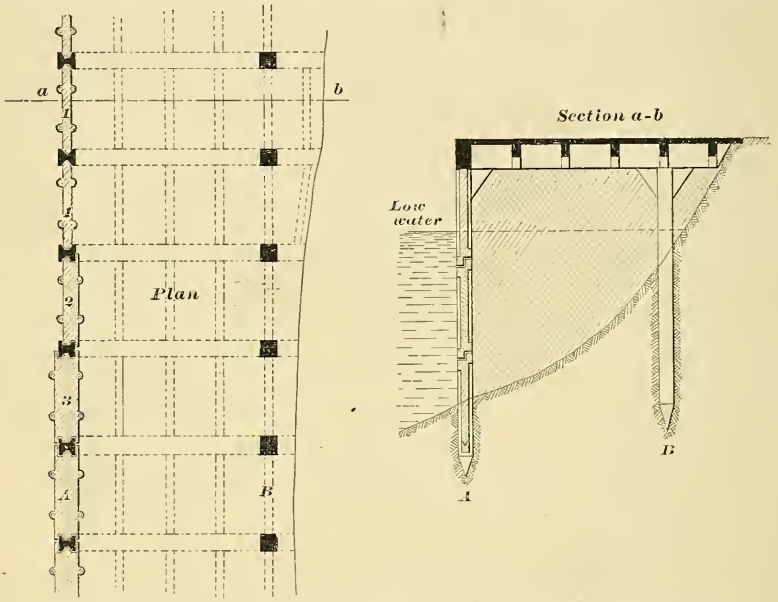


FIG. 8. PROJECT OF WALL WITH PILES AND PANELS OF CEMENT ARMÉ.

sometimes quite violently, and to distribute the effects over all that part of the structure which emerges above the level of the sea.

These braces are made on the spot and united with the piles without any articulation; that is to say, they are cemented into the piles.

At Novorossisk they were constructed in one horizontal plane, at 4 inches above low water, and their dimensions were $11\frac{13}{16} \times 7\frac{7}{8}$ inches. The construction, a single horizontal plane, obviates the possibility of shearing action, caused by lateral efforts, to which the structure would be subjected if the braces were placed at different levels.

The many uses to which armored concrete may be put require

no special form of iron, and any iron, round, square or flat, can be employed.

In the construction of all kinds of armored concrete, even in the making of columns, floorings and walls of buildings, the various parts are molded and constructed on the spot, without the need of heavy and costly hoisting machinery.

With regard to the labor, I would say that experienced or inexperienced men are trained to do the work. In Russia, where competent cement workers could not be obtained, I trained men accustomed to do only ordinary laborer's work, who, in a short time, became efficient in the art.

Observations.—The advantages offered by concrete piles, as compared with wooden piles, are the following:

(1) The contact of the water hardens them more and more.
(2) Their life is unlimited, and they require no repairs.
(3) They are fireproof.
(4) They can be used as columns to support heavy loads.

PLAN OF ARMORED WHARF CONSTRUCTION FOR NEW YORK.

In July, 1902, during my sojourn in New York, at the request of the Department of Wharves and Docks, I made plans for a wharf and its shed, to be entirely constructed of armored concrete.

In this port the great difficulty arises from the great depth of the solid bottom, which, in some parts, is 160 feet, such depth having been given as the maximum.

The plan which I submitted provides for piles 160 feet long, which would be constructed in three pieces and cemented together end to end, the pile in a vertical position.

By reason of the slowness of this method of construction for long piles, and of their cost, which absorbs nearly three-fourths of the cost of the wharf, the Department of Docks asked me, in September, 1902, whether it would be possible to make the piles shorter by taking into account the effort of friction of the mud upon the wooden piles.

In order to scientifically determine the possibility of employing armored concrete piles 83 feet long (the length of the wooden piles), it was necessary (1) to establish the surface of friction of the wooden pile, imbedded 49 feet in the mud, which had been increased by blocks of wood bolted to the pile, hence: Surface of friction of the pile, 110 square feet; surface of friction of applied blocks, 99 square feet; total, 209 square feet. (2) To take into acount the difference of density between armored concrete and wood, a differ-

ence which caused me to reduce the weight of the armored concrete pile.

In consequence my studies bore on a pile, 83 feet long 20 x 20 inches, hollow in the center throughout its entire length, which would give for each linear foot a surface of friction of 6.96 square feet, and, for a depth of 49 feet, 49 x 6.96 = 329.64 square feet, or over and above the wood pile; 329.64 — 209 = 120.64 square feet. This surface might be increased by the surface of friction given by the interior cylinder 8 inches in diameter, but I prefer to neglect this surface of friction.

A hollow pile of the aforesaid length can be constructed, thus eliminating all connections and forming no disturbing element in the usual run of the work. Its cost price is not to be compared with that of the first project.

CITY OF SAN FRANCISCO.

After a careful study of the combined pile—wood and cement—invented by Howard Holmes and Carl Uhlig, of the San Francisco Harbor Commission, I resolved to apply the same idea to the construction of a hollow reinforced concrete pile. I studied the two applications of hollow piles made actually in the harbor of San Francisco. The first consists of a combined pile, having in its center three wooden piles (Wharf No. 10 at the foot of Howard Street), the second being a combined pile with only one wooden pile in the center (Wharf No. 9 being built at the foot of Broadway Street). The work on Wharf No. 9 is being performed by the Hyde Construction Co., to whom I am indebted for information on this subject.

This information, based upon actual tests, showed that the weight of the reinforced concrete pile is almost the same as that of the combined pile, about 22,000 pounds, and, although the former was loaded with fifty tons and the latter with thirty-eight tons, it was subjected to a surface friction of 4.813 pounds per square inch, while the combined wooden pile resulted in 5.877 pounds per square inch of imbedded surface; that is, of it was required twenty-two per cent. more frictional resistance than of the reinforced pile provided in the Villet construction.

Up to a length of 50 feet the pile can be considered as a standard pile, the building of which is an easy matter. If necessary, these piles could be made 83 feet long and over, in which case the outside of friction would be correspondingly increased.

Taking it for granted that experience will show that the Holmes pile will really last twenty-five years, as predicted, the life of such

piles would still be comparatively short when we take in consideration the high cost of placing them. Moreover, such piles are not adapted for any kind of floor but a wooden one.

There is practically no limit to the life of a reinforced concrete pile, and besides they present the great advantage of allowing a reinforced concrete floor to be substituted for the wooden one whenever desired. In view of the possibility of such a floor being required in the future, they can be constructed with two consols or brackets. These consols, in the construction of the present wooden wharves, would increase the bearings of the wooden timbers to 5 feet, instead of the 3 feet allowed with the present method.

I conceived the idea of applying my reinforced concrete pile to the construction of quay walls after the conclusive experiments I had made at Novorossisk, Russia. My method enables me to reduce to a minimum the considerable working stock generally required for building under water, also the unforeseen contingencies so much dreaded in such undertakings.

After a long, careful study of the subject, I rejected the idea of driving in piles joined together, on acount of their excessive cost, and adopted a combination of reinforced concrete piles (square, rectangular or round, with or without longitudinal grooves) with reinforced concrete panels.

The same piles are used for constructing quay walls as for wharves. The shape is immaterial. A square pile, however, is easier to groove longitudinally on its two opposite faces. Said grooves allow the panels to slide between each two piles and can be made in such a manner that the panels will bind each pile to the next one.

Quay walls may be constructed in different ways:

(1) A sea wall along the harbor, Fig. 8, established at the request of the San Francisco Harbor Commission and as per specifications of Mr. Norton, chief engineer. This project comprises:

(A) A first row of piles, in which the panels slide. This row of piles is connected with a second row (called the steadying piles) by means of reinforced concrete beams, binding perpendicularly one pile of the first to the corresponding pile of the second row. These steadying piles are further connected with one another by a beam (B) running parallel to the first row.

Should one row of steadying piles not be sufficient, a second one can easily be established parallel to the first.

(2) Such a wall can also be constructed by means of parts "A" running parallel and connected with one another by beams

running perpendicularly from one to the other. In this case each part serves as a steadying line for the other.

After the work is completed, the space between the two rows can easily be filled up.

(3) *Construction of Moles.*—My method of constructing quay walls may also be applied to the erection of moles, and this is done by constructing a certain number of parts, "A," connected with one another laterally and perpendicularly.

The intervals can be filled up after completion of the work.

Other applications of this method may arise at any moment.

Whatever may be the requirements, the intervals can be filled up with the material brought up by the dredges, which may be working on each side of the walls in order to excavate to the necessary depth at the foot of same, and, in the case foreseen in description No. 2, vessels will be enabled to make fast on both sides of the wall.

One of the designs allows the construction of a wooden floor resting on wooden beams, whereas the other provides for a concrete floor resting on reinforced concrete beams.

The panels may be constructed of different thicknesses. (See 1, 2, 3, Fig. 8.)

In (1) the panels simply slide in the grooves of the piles. This form is used for the upper part of the wall only, where the lateral pressure of the adjacent ground is considerably less than nearer to the bottom.

In (2) the panels slide both in the grooves and along one of the faces of the pile. For a depth of 20 feet, as required for the harbor of San Francisco, (1) and (2), thus constructed, would be sufficient. Panel (2), having a thickness of $15\frac{3}{4}$ inches, must, at a depth of 20 feet, withstand a lateral pressure of about 1800 pounds per square foot.

In (3) the panels slide in grooves and along both faces of the piles. This form can be used for great depths.

In each case, and whatever may be the kind of panel required, the lower panel is supplied on its lower edge with a triangular steel shoe, in order to facilitate driving.

The succeeding panels overlap one another, and are bound together by means of semi-cylindrical flanges, which are made at the same time and on each side of the panels. Through these flanges are driven iron bars, one extremity of which is mortised. The mortises make it possible to securely fasten together the panels by means of cotters before they are immersed. After the cotters are

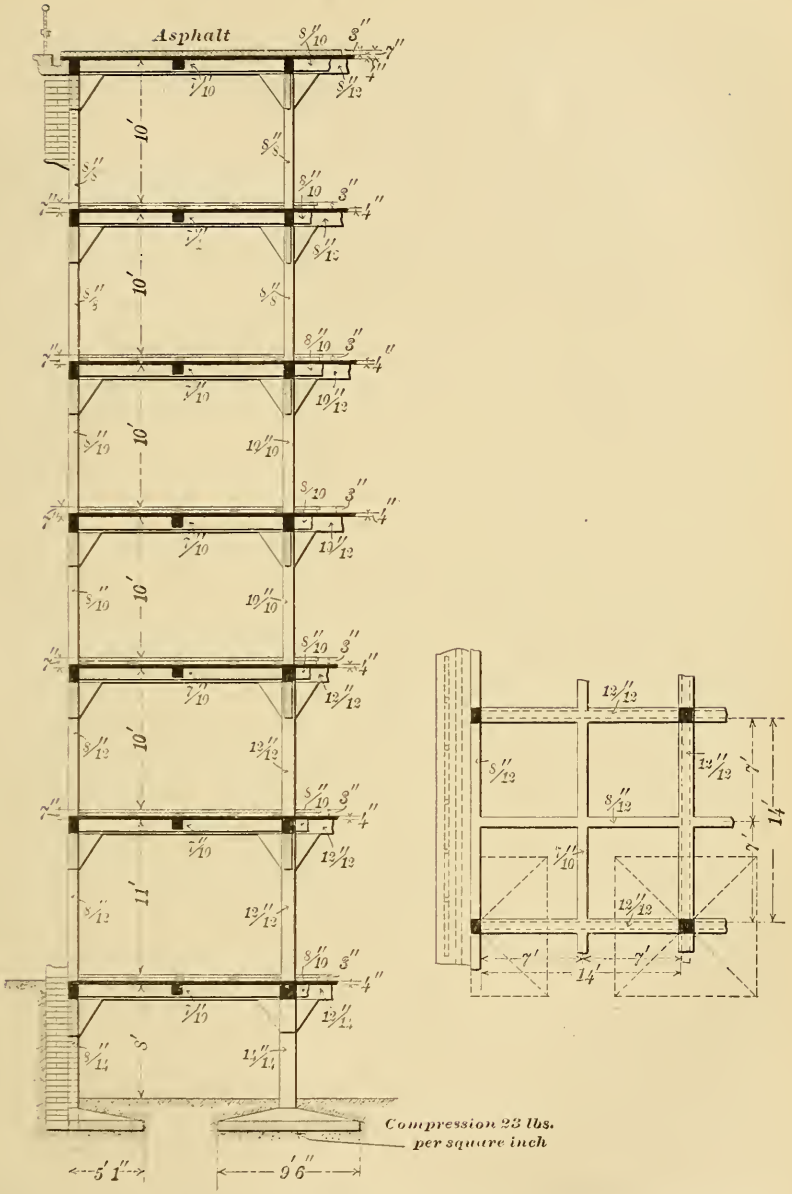


FIG. 9. CONCRETE-METAL BUILDING CONSTRUCTION. PERMANENT FLOOR LOAD, 60 POUNDS PER SQUARE FOOT.

driven in they, as well as the iron bars, are covered with cement in order to prevent oxidation.

The panels are bound to one another and immersed as soon as completed. The above-mentioned triangular steel shoe under the

action of the weight, which increases with every new panel, facilitates penetration through the mud. Such penetration can also be increased by having each part driven in by means of the hammer, the same as for the piles.

Buildings.—In the design of a seven-story building for San Francisco, Fig. 9, the somewhat large dimensions of the sleepers can be reduced by simply increasing the size of the iron bars imbedded in the concrete without increasing the thickness of the latter. (See plan No. 1.)

For this kind of construction, as also for any application of reinforced concrete beams or piles, there is no necessity of having:

(1) Any special size of iron, any joint or rivets; ordinary iron bars being sufficient.

(2) Any heavy or cumbersome hoisting machinery; a small elevator for conveying the iron, the cement and other material will be all that is required.

The advantages of reinforced concrete are many:

Supplies of material are easy to be had; no cumbersome material or machinery is required; rapidity in constructing; lightness; strength; equal or superior resistance as compared with brick or stone work, although both volume and weight are less; fireproof and waterproof qualities unexcelled, etc.

Besides reinforced concrete being much lighter, foundations will not need to be so deep and so strong as for ordinary brick buildings.

The incombustibility and the inalterability of reinforced concrete seem sometimes to be doubted, although these qualities have been proved by numerous and conclusive experiments.

OBITUARY.

George F. Allardt.

Member of the Technical Society of the Pacific Coast.

Another of the charter members of the Technical Society of the Pacific Coast has passed away.

George Frederick Allardt died on the 27th of July, 1903, in Oakland, near San Francisco.

Identified with engineering in California from the early development of the State, Mr. Allardt has been better known to the public than perhaps any other engineer on the Pacific Coast. From the time of his arrival here in 1858 up to the day of his death he was professionally active and variously employed. His work was connected with many of the enterprises that have been the most prominent of the far West. The early period of our State's history called for men that were resourceful, adaptable and of the greatest energy. Their field of labor was extensive in the most daring application of the term, and almost entirely unprepared; analogous cases were lacking when these men were called upon to undertake vast propositions with the most meager facilities, throwing them entirely upon their own mental fertility to devise not only the design of the project itself but also to prepare the ways and means for carrying it out successfully.

Allardt passed through this trying period. He was one of the pioneer engineers of the State of California, and as such will always be remembered. His labors, carried on almost uninterruptedly to the day of his death, deserve the fullest recognition, and the Technical Society takes great pride in now pointing to this honorable career and proclaiming him one of the old guard, who will never be forgotten by those who had the good fortune to know him.

Through many years he was a very active member of the Society, one who never shirked any of the responsibilities and duties requested of him. It is well remembered that in the formation and organization of a representative body of civil engineers in California, a movement emanating from the Technical Society, Mr. Allardt labored for many days in the framing of a constitution and regulations which were to be a guide to the profession and intended to place it upon a higher basis.

In all such matters his counsel and advice, based upon his long and valuable experience, were freely given to his colleagues

at all times, and whatever he did in this way was done with such a cheerful manner and with a certain inimitable humor that made his presence wherever wanted not only a great profit but a great pleasure.

There was certainly never a more congenial companion. He had the rare faculty of an absolutely even temper, and in his intercourse with his fellow-men he showed but one side,—that bright and cheerful disposition which was natural to him.

What he has performed professionally will always speak for itself. It was well done, and it is well known to those who with him have been residents of the Golden State from its earlier romantic history.

A few of the main points of his busy career have been touched upon by his son, Mr. C. F. Allardt, who has courteously furnished the Technical Society with the following short sketch:

"George Frederick Allardt, born February 1, 1833, in Lauban, Prussia, was descended from Huguenot ancestors, who went into Germany at the time of the expulsion of the Huguenots from France. His father was a minister of the German Reformed Church. When George was six months old, the family came to America and settled in Cleveland, Ohio, where his father had charge of the German Church, and where the boy received his education. After he had graduated from the high school he went into a drug store to learn the drug business. This business proving hard on his health, he began the study of civil engineering, and soon obtained a position on the Cleveland, Painesville and Ashtabula Railway. He was also employed for a time in the office of the city engineer, of Cleveland.

"In 1858 he came to California by way of the isthmus. His first work here was as a draughtsman for the San Francisco and San José Railway. He was also in the office of the surveyor general, and surveyed many Spanish grants. In 1863 he went to the East for a visit at his old home. In the same year he returned and went to the Reese River country during the mining excitement, surveying mines and doing a general surveying business. In 1865 he went to Cleveland and married Miss Emma Kluegel, whom he brought to California and with whom he settled in San Francisco.

"In 1865 the Harbor Commissioners offered a prize for the best plan for a sea wall for San Francisco. Mr. Allardt's plans were adopted, and the sea wall is now built according to these plans.

"In 1868 Mr. Allardt was appointed chief engineer of the Tide Land Commission, and while holding this position he surveyed all

the tide lands in San Francisco Bay. He held this position for seven years.

"In 1876 he was appointed assistant engineer on the commission to investigate all the available water supplies for the city of San Francisco, and thus became thoroughly familiar with the water question. He next became engineer for the farmers in the Debris suit between the farmers and miners. This lasted for a number of years, and was won by the farmers. In 1889 he went to Honolulu, and reported on the irrigation of sugar lands on the islands of Oahu and Kauai. His report was followed, and there are now many plantations pumping water for irrigation purposes with great success. In 1890 he made another trip to Honolulu to make plans for a sewerage system and for deepening the bar of Honolulu Harbor. These works were carried out.

"In 1892 he was appointed the surveyor for the partition of the San Pablo Rancho (Emeric *vs.* Alvarado). This was in the courts thirty years, the land involved consisting of over 17,000 acres. He was engaged in this work about three years. This was the largest survey of its kind ever made in California.

"He experted for the Spring Valley Water Works in their lawsuits, being the company's chief witness. He was also one of the experts for the city of Oakland in suit against the Contra Costa Water Company in 1900.

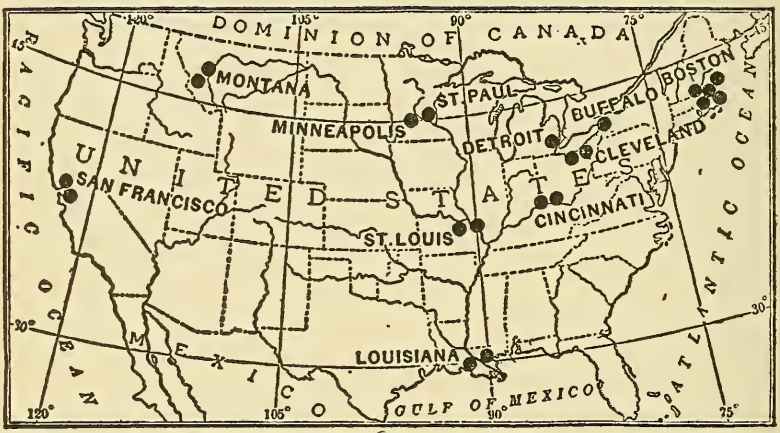
"He made a specialty of hydraulic engineering. Besides the more important work mentioned above, he did a great deal of work in all lines of civil engineering, including plans for sewerage systems, irrigating projects, water works and land surveying, having his office in San Francisco.

"Twenty years ago he foresaw, from his intimate knowledge of topographical conditions, that Point Richmond would become a great railway terminus, and he acquired a large interest in the tide lands there at that time.

"His life companion, his faithful wife, survives him, as do also three children, Charles F. Allardt, Frederick A. Allardt and Lotta Allardt."

And now that this useful life is ended our Society expresses its deepest sympathy with the family of our departed member, and resolves to hand this token of its sense of loss in the death of George F. Allardt to his widow, with the assurance that we, too, have lost a friend and counselor.

Otto von Geldern,
Committee.


DOMINION OF CANADA
MONTANA
ST. PAUL
MINNEAPOLIS
BUFFALO
BOSTON
DETROIT
CLEVELAND
UNITED STATES
SAN FRANCISCO
CINCINNATI
ST. LOUIS
LOUISIANA
MEXICO
GULF OF MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN
120°
105°
90°
75°
30°

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RAINFALL AND RUN-OFF OF NEW ENGLAND, ATLANTIC COAST AND SOUTHWESTERN COLORADO STREAMS.

BY WILLIAM O. WEBBER, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, September 16, 1903.*]

YOUR President has asked the writer to submit the tables in regard to the flowage of the New England and Eastern streams recently compiled in connection with an important case where the amount of water taken from a manufacturing concern was of vital interest as a measure in part of the damages sustained by such taking. As a result of the testimony submitted in this case by numerous engineers on both sides, the writer is of the opinion that too much stress has been laid upon the records of Sudbury River, as universal measure of the flowage of streams in this vicinity, and also that not enough consideration is given to the *character* of watersheds in contradistinction to the *area* of watersheds in regard to the amount of water per square mile contributed at different seasons of the year. There is no doubt that the measurements of the Sudbury River are eminently safe measurements to take when computing the possibilities of contribution from a similar watershed for town waterworks and other municipal purposes, where it is very essential that the minimum amount obtainable is the measure of the development and the value of the watershed for such purpose. It then becomes analogous to the letters which one of the United States Fish Commissioners used to receive in regard to the propagation of trout. Many of these letters inquired how many trout could be raised upon a stream which was absolutely

*Manuscript received September 3, 1903.—Secretary, Ass'n of Eng. Socs.

dry for only six weeks in the year, and of course the answer is apparent. This, however, is not true of the use of a stream for manufacturing purposes. It would be unwise to restrict the development of a stream for manufacturing purposes to the minimum amount which might be contributed in the driest period of an extremely dry season, as this would probably occur only once in every four or five years. It therefore becomes pertinent to ascertain what the probable low flow of a certain stream may be in an ordinary season with proper conservation and reservoirs, and before the extent of such reservoir systems can be estimated a study of the probable average contribution of the watershed supplying such stream must be made. To obtain such information by actual measurements of the stream in question would require a series of observations extending over so long a period as to practically prohibit the development of the stream, and measurements taken for a short period only are practically worthless, except as an indication when taken into consideration with the contribution of other developed streams for the same period, where the known amount of power usually available on the developed stream is easily ascertained. The writer therefore submits the following tables, in the hope that it may throw some light on the subject and at least cause some discussion. Knowing full well that the data do not extend over nearly so long periods as might be desirable, and while admitting that their purpose was for comparison with the stream then in question, of which only a limited amount of data was available, still, in the light of other figures with which he is familiar, and which he hopes to have the privilege of submitting later, and which corroborate his opinions, he hopes that they may throw some further light on the subject.

First, in reference to table marked XXIII, it will be noticed that the mean contribution in cubic feet per square mile is remarkably uniform, and is oftentimes much larger on a small watershed than on a larger watershed. The minimum is usually larger on a large watershed than on a small watershed, and the maximum per square mile is usually larger on a small watershed than on a large watershed, but so much depends on the character of the watershed that the writer believes that each watershed should be carefully studied in all its aspects before all its deductions can be made with any certainty.

The table marked I would seem to indicate that in New England and Eastern streams in dry years about $1\frac{1}{4}$ cubic feet per second per square mile could be relied upon, whereas in wet years

at least $1\frac{3}{4}$ is available, and in the five dry months of dry years about $\frac{1}{2}$ cubic foot per square mile is available, as against double that amount in the five dry months of wet years.

Tables II, III and IV are intended to show the percentages of the rainfall collected in different streams during the dry months of the year, and also during the whole year for wet and dry seasons. These tables would seem to show that in wet years we might reasonably expect to collect 25 per cent. of the rainfall in the five dry months, whereas in dry years from 10 per cent. to 15 per cent. is all that can be expected on small streams and 20 per cent. on larger streams. In wet years we may expect to collect 57 per cent. of the rainfall. In average years 45 per cent. and in dry years 32 per cent., while the maximum per cent. is found to run as high as 70 per cent.

In the tables presented the years 1894 and 1896 were about average years. The year 1895 was rather a dry year, and the years 1897 and 1898 were wet years.

Mr. James B. Francis, the eminent hydraulic engineer, once told the writer that 1 cubic foot per second per square mile would represent the maximum safe development of a stream for power and manufacturing purposes, and in the table marked XX the writer has deduced that the absolutely safe development of a stream would be at the rate of .567 cubic foot per second per square mile. The average flow of streams for the five dry months of wet seasons is 1.435 per cubic foot per second per square mile. The average of these gives the 1 cubic foot per second per square mile which Mr. Francis considered as the maximum rate for commercial development.

It is interesting to compare this with the table marked XXI, based on the average collection per month, arranged in regard to the dryness of months and based on the average rainfall in this vicinity from 1818 to 1897, inclusive. This again shows 1 cubic foot per second for the six dry months, which, curiously enough, in this table occurs in the month of June, and corroborates again an old saying of Mr. Francis that "June flow" in an average year might safely be taken as the average commercial flow of a stream.

The writer has measured the flow of many streams in this country, going as far west as the San Miguel, in Southwestern Colorado, as far north as the Ontonagon, in the Northern Michigan Peninsula, and as far south as the Catawba, in South Carolina. The data thus collected strengthen his opinion in regard to the results of stream measurements, and it should be clearly understood that the accompanying tables and deductions refer only to

New England and other Eastern Atlantic Coast streams, as the conditions governing streams in other sections of the country are entirely different, owing to the climatic conditions, so that the maximum flow of the Rocky Mountain streams usually occurs at the time of the minimum flow of our streams in New England, and yet the same general principles seem to govern all of the results, and, in the writer's opinion, the only way in which to form an accurate opinion as to the proper development of any stream is to study that particular stream in relation to its own watershed and the average rain-fall and run-off found by collecting actual data in the immediate vicinity.

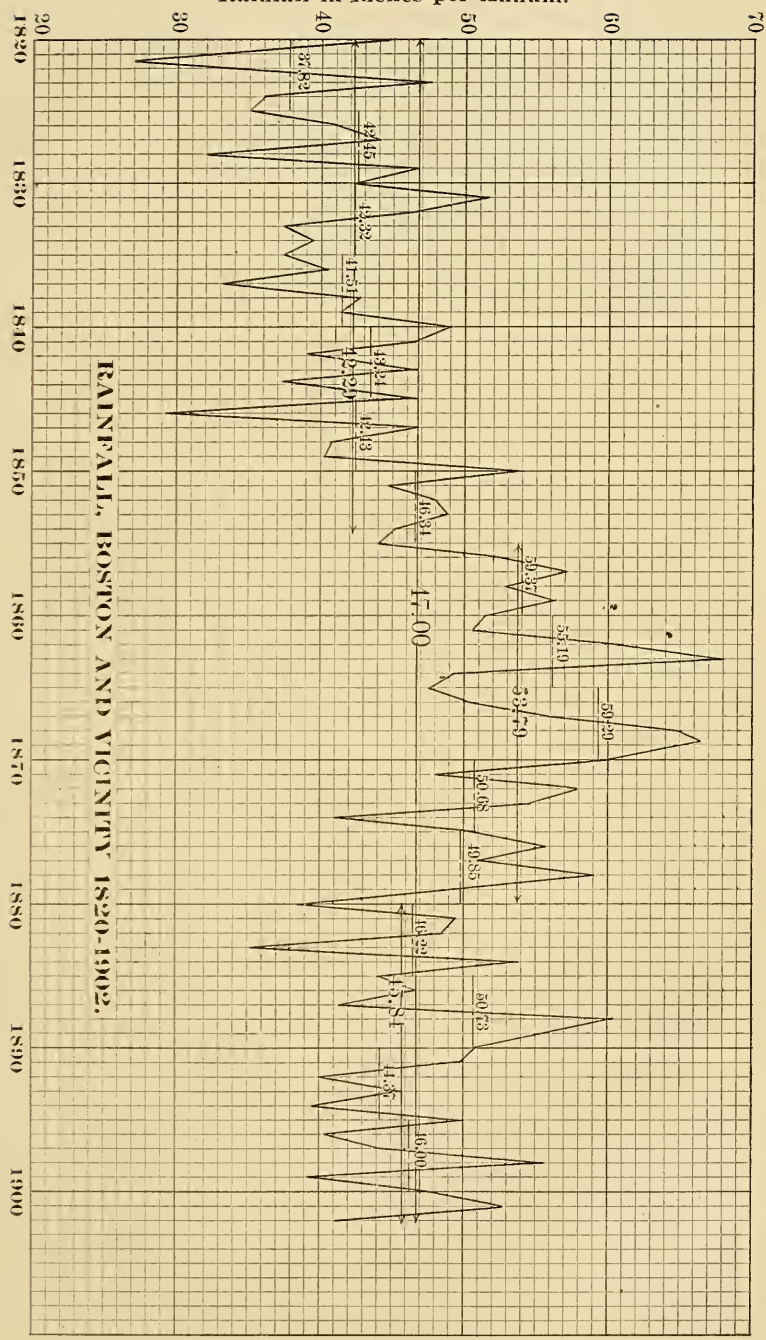
In the Rocky Mountain regions the amount of rainfall varies very much with the altitude, there being a steady increase of rainfall as the altitude increases up to a certain point, and then a remarkably rapid falling off or entire cessation of rainfall. Very little rain falls above the timber line, and, in fact, the only contributions of moisture above that elevation is largely due to the snow which is blown up horizontally from the lower elevations. The average rainfall in Colorado, west of the Rocky Mountains, on the Mesa, which lies at an elevation of about 7000 feet, is fifteen inches. This increases as the higher altitudes are reached, so that at Telluride, Ruby, Summit and other points averaging about 10,000 feet elevation the average rainfall is about 26 inches.

The freshets in these streams occur in July, when the large deposits of snow in the crevices and ravines on the upper mountain regions begin to melt, and it is usually not until September that these great deposits of snow and ice are practically all melted away. The low flow of the streams occurs in January, February and March, when everything is entirely frozen up.

There is also another phenomenon in connection with the Western Rocky Mountain streams, in that large quantities of water deposited in the upper mountain regions disappear before reaching the Mesa, and reappear again in the lower canons through underground passages.

The writer is of the opinion that there is more general misinformation prevalent as to the amount of water available in these watersheds bounding the arid region of the Southwest than is usually conceded, and that very many of the irrigation schemes are doomed to commercial failure for reason of insufficient data.

The Government has maintained very few rain gauges at extremely high altitudes, as this means isolation to the observer for a period usually covering six months.


Rainfall in inches per Annum.
20
30
40
50
60
70
1820
1830
1840
1850
1860
1870
1880
1890
1900
RAINFALL, BOSTON AND VICINITY 1820-1902.
47.00
37.82
42.45
43.32
41.51
43.24
42.13
46.54
50.37
55.19
59.29
50.08
49.85
49.22
45.54
50.73
46.00

The writer is of the opinion that at some later date it might interest the Society to hear parts of a report on an irrigation scheme to bring out some of the engineering features involved.

In the Northern Michigan Peninsula, where the run-off is largely influenced by the proximity of the Great Lakes, another set of conditions prevails. The rainfall is extremely large, owing to the fact that the country is largely covered with forests and swamps, lying at a comparatively slight elevation above that of the lakes, so that the fall in the average streams is remarkably slight and the amount of water held back and stored is very large.

TABLE I.

COMPARISON OF THE FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE OF EASTERN STREAMS IN WET AND DRY YEARS.

Dry Years.

	Cochituate.		Sudbury.		Mystic.		Merrimac.		Connecticut.		Perkiomen.		Neshaminy.		Tohickon.	
	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.
1894	0.46	0.96	0.55	1.19	0.61	1.06	0.84	1.15	0.65	0.97	.....	.....	.....	.....	.....	.....
1895	0.55	1.49	0.42	1.79	0.61	1.28	0.53	1.28	0.64	1.19	0.43	1.15	0.49	1.20	0.37	1.38
1896	0.57	1.48	0.40	1.58	0.58	1.44	0.69	1.47	0.64	.....	0.69	1.26	0.52	1.25	0.76	1.46
Average, 5 months .	0.53	.....	0.46	.....	0.60	.....	0.68	.....	0.64	.....	0.56	.....	0.50	.....	0.56	.....
Average, year . . .	.....	1.31	.....	1.52	.....	1.26	.....	1.30	.....	1.08	.....	1.20	.....	1.22	.....	1.42

Wet Years.

1888	1.15	2.29	1.14	2.62	1.04	2.30	1.86	2.91	1.85	2.00	1.19	2.21	0.74	2.10	1.42	2.93
1894	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.82	1.87	2.01	1.90	2.23	3.29 !
1897	0.78	1.25	1.12	1.74	1.03	1.47	1.81	.....	.....	.....	1.28	1.45	1.66	1.56	1.72	1.79
Average, 5 months .	0.96	.....	1.13	.....	1.02	.....	1.83	.....	1.85	.....	1.43	.....	1.47	.....	1.79	.....
Average, year . . .	.. ...	1.77	.....	2.18	.....	1.88	.....	2.91	.....	2.00	.....	1.84	.....	1.85	.....	2.34

TABLE II.

Percentages of Rainfall Collected.

Connecticut River.

Wet Years.

	May.	June.	July.	August.	September.	October.	Year.
	217.0	70.3	15.2	23.2	16.0	41.1	1873
	146.9	65.4	38.2	33.8	26.7	28.9	1874
	113.8	29.8	22.9	22.8	30.4	22.8	1878
Sum..	477.7	165.5	76.3	79.8	73.1	92.8	. . .
Avg. .	159.2	55.2	25.4	26.6	24.4	35.9	. . .

Dry Years.

	96.3	32.3	15.70	19.5	15.4	18.6	1880
	97.6	33.6	21.20	24.0	39.4	18.2	1881
Sum..	193.9	65.9	36.90	43.5	54.8	36.8	. . .
Avg. .	96.9	32.9	18.45	21.7	27.4	18.4	. . .

Cochituate River.

Wet Years.

	May.	June.	July.	August.	September.	October.	Year.
	82.2	119.1	15.1	19.5	29.8	33.4	1873
	81.7	40.8	30.0	19.1	34.3	50.3	1874
	112.0	47.3	13.2	27.1	32.0	18.7	1887
	51.2	25.8	28.1	14.9	26.2	51.9	1888
	32.9	37.1	17.9	75.0	36.4	49.6	1889
	34.9	79.1	14.2	13.9	21.6	33.7	1890
Sum..	394.9	349.2	118.5	169.5	180.3	237.6	. . .
Avg. .	65.8	58.2	19.7	28.2	30.0	39.6	. . .

Dry Years.

	22.2	4.5	4.7	6.1	14.3	16.6	1880
	39.6	27.0	5.8	7 6	10.8	6.4	1881
	32.8	33.1	1.7	6.2	10.5	37.9	1882
	31.9	3.7	0.6	18.6	47.4	11.5	1883
	47.6	14.4	0.0	4.8	15.5	15.0	1885
	43.0	35.5	11.1	7.8	10.7	13.4	1886
Sum..	217.1	118.2	23.9	51.1	109.2	100.8	. .
Avg. .	36.2	19.7	3.9	8.5	18.2	16 8	. . .

TABLE III.

Percentages of Rainfall Collected.

Mystic River.

Wet Years.

	May.	June.	July.	August.	September.	October.	Year.
	104.9	24.5	22.6	12.8	29.7	44.2	1879
	50.7	29.9	33.3	51.9	14.1	13.6	1881
	112.0	47.3	13.2	27.1	32.0	18.7	1887
	59.6	38.1	17.5	8.8	15.3	55.3	1888
	46.9	57.0	15.8	52.2	22.5	33.7	1889
	47.6	56.9	19.0	12.7	15.6	29.5	1890
Sum. .	418.7	253.7	121.4	165.5	129.2	195.0	. . .
Avg. .	69.8	42.3	20.2	25.9	21.5	32.5	. . .

Dry Years.

	47.3	34.3	9.2	14.7	31.7	13.5	1880
	40.4	38.6	14.9	20.8	6.3	30.0	1882
	33.5	31.8	10.8	25.7	12.1	7.2	1883
	43.0	35.5	11.1	7.8	10.7	13.4	1886
	57.0	22.8	13.3	11.3	19.3	12.1	1891
	25.3	125.8	14.2	15.1	14.3	10.5	1894
Sum. .	246.5	288.8	73.5	95.4	94.4	86.7	. . .
Avg. .	41.1	48.1	12.2	15.9	15.7	14.4	. . .

Sudbury River.

Wet Years.

	May.	June.	July.	August.	September.	October.	Year.
	59.5	24.0	16.0	12.8	10.4	23.8	1875
	49.0	42.8	21.0	19.4	13.0	11.2	1881
	60.3	28.7	14.9	10.9	23.2	71.4	1888
	53.4	40.3	12.6	61.2	30.9	51.6	1889
Sum. .	222.1	135.8	64.5	104.3	77.5	158.0	. . .
Avg. .	55.5	33.9	16.1	26.1	19.4	39.5	. . .

Dry Years.

	50.0	14.2	5.0	5.3	8.6	4.8	1880
	40.0	21.6	7.7	19.1	10.4	5.9	1883
	42.9	23.9	6.3	4.1	7.0	8.0	1886
	154.5	26.9	5.5	7.2	14.5	12.0	1887
	51.7	18.9	7.8	6.1	14.7	9.8	1891
	77.8	31.9	11.0	5.9	10.8	9.7	1893
Sum. .	416.9	137.4	43.3	47.7	66.0	50.2	. . .
Avg. .	69.5	22.9	7.2	7.9	11.0	8.3	. . .

Percentage Collected in Wet Year—1888.		Percentage Collected in Dry Year—1883	
Cochituate	54.4	Cochituate	32.4
Sudbury	62.2	Sudbury	34.1
Mystic	54.8	Mystic	29.8
	171.4		96.3
Average	57.13	Average	32.1

Percentage Collected—Average Year.		Maximum Percentage Collected.	
Cochituate	43.12—1863-95	Cochituate	69.1%—1891
Sudbury	48.00—1875-95	Sudbury	62.2%—1888
Mystic	44.60—1878-95	Mystic	60.3%—1891
	135.72		191.6%
Average	45.24	Average	63.87%

TABLE IV.

Average Percentage of Collections.

	May.	June.	July.	August.	September.	October.
Connecticut . .	132.2	36.5	21.30	21.8	29.30	28.30
Potomac	46.3	36.8	20.50	20.5	27.50	45.70
Merrimac . . .	141.0	32.3	22.20	27.6	37.80	37.50
Cochituate . . .	53.5	32.6	13.89	17.2	29.94	27.16
Mystic	69.1	39.0	17.10	18.6	20.10	20.50
Summary . . .	442.1	176.9	94.99	105.70	144.64	159.16
Average	88.4	35.4	18.99	21.14	28.93	31.83

Summary of Percentage of Rainfall Collected.

Wet Years.

	May.	June.	July.	August.	September.	October.
Connecticut . .	159.2	55.2	25.4	26.6	24.4	30.9
Mystic	69.8	42.3	20.2	25.9	21.4	32.5
Sudbury	55.5	33.9	16.1	26.1	19.4	39.5
Cochituate . . .	65.8	58.2	19.7	28.2	30.0	39.6
Summary . . .	350.3	189.6	81.4	106.8	95.2	142.5
Average	87.4	47.4	20.7	24.7	23.8	35.6

Summary of Percentage of Rainfall Collected.

Dry Years.

	May.	June.	July.	August.	September.	October.
Connecticut . .	96.9	32.9	18.4	21.7	27.4	18.4
Mystic	41.4	48.1	12.2	15.9	15.7	14.4
Sudbury	69.5	22.9	7.2	7.9	11.0	8.3
Cochituate . . .	36.2	19.7	3.9	8.5	18.2	16.8
Summary . . .	244.0	123.6	41.7	54.0	72.3	57.9
Average	61.0	30.9	10.4	13.5	18.1	14.5

TABLE V.

COMPARISON IN THE FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE OF EASTERN STREAMS IN THE MONTHS OF JUNE, JULY, AUGUST, SEPTEMBER AND OCTOBER.

	1894. 5 MONTHS, JUNE-OCTOBER.		1895. 5 MONTHS, JUNE-OCTOBER.		1896. 5 MONTHS, JUNE-OCTOBER.		1897. 5 MONTHS, JUNE-OCTOBER.	
	Average.	Total.	Average.	Total.	Average.	Total.	Average.	Total.
Cochituate	0.416	2.070	0.721	3.605	0.682	3.41	0.737	3.685
Sudbury	0.406	2.030	0.651	3.255	0.474	2.37	0.868	4.340
Mystic	0.480	2.400	0.626	3.130	0.606	3.03	0.786	3.930
Merrimac	0.634	3.170	0.622	3.110	0.670	3.35	1.468	7.342
Connecticut	0.510	2.550	0.454	2.270	0.676	3.38	.....	.....
Perkiomen	0.950	4.750	0.300	1.500	0.866	4.33	0.630	3.150
Neshaminy	0.987	4.935	0.385	1.925	0.620	3.10	1.216	6.080
Tohickon	1.107	5.535	0.274	1.375	0.888	4.44	0.932	4.660
Average	0.686	3.430	0.504	2.521	0.685	3.42	0.829	4.148
Average of Cochituate, Mystic and Sudbury	0.434	.....	0.666	.....	0.587	.....	0.797	0.621

COMPARISON OF FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE OF EASTERN STREAMS.

	1894.				1895.				1896.		
	Average of 5 months, May-Sept.	Total of 5 months, May-Sept.	Average for year.	Total for year.	Average of 5 months, May-Sept.	Total of 5 months, May-Sept.	Average for year.	Total for year.	Average of 5 months, May-Sept.	Average for year.	Total for year.
Sunbury	0.55	2.75	1.19	14.28	0.420	2.10	1.79	21.48	0.404	1.582	18.99
Mystic	0.61	3.05	1.06	12.74	0.610	3.05	1.28	15.42	0.580	1.442	17.30
Merrimac	0.84	4.22	1.15	13.80	0.530	2.66	1.28	15.36	0.690	1.466	17.59
Connecticut	0.65	3.28	0.97	11.65	0.640	3.23	1.19	14.32	0.640	.....	.....
Perkiomen	1.82	9.10	1.77	21.20	0.430	2.15	1.15	13.86	0.690	1.265	15.18
Neshaminy	2.01	10.05	1.90	22.83	0.490	2.45	1.20	14.37	0.520	1.250	15.00
Tohickon	2.23	11.15	2.29	27.50	0.370	1.85	1.88	16.55	0.760	1.464	17.57
Cochituate	0.46	2.30	0.96	11.50	0.550	2.75	1.49	17.85	0.568	1.485	17.82
Average	1.14	.....	1.41	.....	0.505	.....	1.34	.....	0.606	1.422	.....

TABLE VI.

COMPARISON OF FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE OF EASTERN STREAMS.

	1888.				1897.			
	Average of five months, May-Sept.	Total of five months, May-Sept.	Average for year.	Total for year.	Average of five months, May-Sept.	Total of five months, May-Sept.	Average for year.	Total for year.
Cochituate	1.15	5.75	2.29	27.40	0.78	3.88	1.25	15.09
Sudbury	1.14	5.70	2.62	31.44	1.12	5.60	1.74	20.82
Mystic	1.04	5.20	2.30	27.54	1.03	5.15	1.47	17.64
Merrimac	1.86	9.29	2.91	34.92	1.81	9.07	.....	.....
Connecticut	1.85	9.28	2.00	24.01	.....	.....	.....	.....
Perkiomen	1.19	5.95	2.21	26.53	1.28	6.40	1.45	17.40
Neshaminy	0.74	3.70	2.10	25.20	1.66	8.30	1.56	18.74
Tohickon	1.42	7.10	2.93	35.20	1.72	8.60	1.79	21.51
Average	1.30	.....	2.42	.....	1.34	.....	1.54	.....

FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE, SIX MONTHS—MAY, JUNE, JULY, AUGUST, SEPTEMBER AND OCTOBER, 1897.

	May.	June.	July.	August.	September.	October.	Summary.	Average.
Cochituate	1.21	1.07	0.65	0.54	0.41	0.37	4.89	.....
Sudbury	1.41	1.49	1.51	0.91	0.28	0.15	5.75	.....
Mystic	1.59	1.96	0.44	0.83	0.36	0.34	5.52	.....
Perkiomen	3.45	0.83	1.35	0.52	0.26	0.19	6.60	.....
Neshaminy	2.38	2.21	0.52	0.96	0.20	0.14	8.46	.....
Tohickon	4.03	1.54	2.32	0.63	0.11	0.06	8.69	.....
Average	2.34	1.51	1.47	0.73	0.27	0.21	6.65	1.11

TABLE VII.

FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE, SIX MONTHS—MAY, JUNE, JULY, AUGUST, SEPTEMBER AND OCTOBER, 1897.

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.	Merrimac.
May	1.210	1.41	1.59	3.45	2.38	4.03	2.214
June	1.070	1.49	1.96	0.83	2.21	1.54	2.782
July	0.650	1.51	0.44	1.35	2.57	2.32	2.363
August	0.545	0.91	0.83	0.52	0.96	0.63	1.110
September	0.410	0.28	0.36	0.26	0.20	0.11	0.604
October	0.370	0.15	0.34	0.19	0.14	0.06	0.483
Average, 5 months, May-September	0.777	1.12	1.03	1.28	1.66	1.72	1.814
Average, 6 months, May-October	0.710	0.96	0.92	1.10	1.41	1.45	1.592
Average, 5 months, June-October	0.610	0.87	0.77	0.63	1.22	1.93	1.468

COMPARISON OF RAINFALL COLLECTED IN EASTERN STREAMS, SIX MONTHS—MAY, JUNE, JULY, AUGUST, SEPTEMBER AND OCTOBER, 1897.

PER CENT. COLLECTED.

	May.	June.	July.	August.	September.	October.	Average.
Cochituate	32.80	27.80	15.70	19.20	17.80	48.60	26.98
Sudbury	37.34	37.29	21.56	30.00	10.73	35.74	28.77
Mystic	37.04	38.45	13.14	27.62	13.08	99.23	38.09
Perkiomen	46.00	29.00	20.00	22.00	18.00	11.00	23.90
Neshaminy	36.00	47.00	33.00	32.00	16.00	7.00	28.33
Tohickon	52.00	33.00	32.00	19.00	6.00	4.00	24.33
Average	40.03	35.42	22.56	24.80	13.60	33.93	28.40

TABLE VIII.

PER CENT. COLLECTED, 1897.

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.	Merrimac.
May	32.8	37.34	37.04	45.0	36.00	52.00	56.00
June	27.8	37.29	38.45	29.0	47.00	33.00	51.70
July	15.7	21.56	13.14	20.0	33.00	32.00	40.40
August	19.2	30.00	27.62	21.0	32.00	19.00	37.60
September	17.8	10.73	13.08	18.0	16.00	6.00	35.00
October	48.6	35.74	99.23	10.0	6.00	4.00	63.60
Average, 5 mos., May-September	22.66	27.38	25.87	26.6	32.80	28.40	44.10
Average, 6 mos., May-October	26.98	28.77	38.09	23.9	28.33	24.33	47.40
Average, 5 mos., June-October	25.82	27.06	38.30	19.6	26.80	18.80	45.66

TABLE IX.

Comparison of Eastern Streams. Flow in Cubic Feet per Second per Square Mile, Six Months—May, June, July, August, September and October, 1896.

	May.	June.	July.	August.	September.	October.	Summary.	Average.
Cochituate	0.54	0 64	0.32	0.410	0.93	1.110	3.95	.....
Sudbury	0.56	0.62	0.15	0.090	0.60	0.910	2.93	.....
Mystic	0.67	0.68	0.34	0.290	0.95	0.770	3.70	.....
Perkiomen	0.40	0.43	1.74	0.290	0.59	1.280	4.73	.....
Neshaminy	0.33	0.36	0.90	0.170	0.86	0.810	3.43	.....
Tohickon	0.27	0.16	2.20	0.160	1.00	0.920	4.71	.....
Average	0.46	0.48	0.94	0.235	0.82	0.966	3.91	0.65

Comparison of Eastern Streams. Flow in Cubic Feet per Second per Square Mile, Six Months—May, June, July, August, September and October, 1896 (*Concluded*).

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.	Merrimac.	Connecticut.
May	0.540	0.560	0.670	0.400	0.33	0.27	1.149	1.195
June	0.640	0.620	0.680	0.430	0.36	0.16	0.770	0.661
July	0.320	0.150	0.340	1.740	0.90	2.20	0.433	0.451
August	0.410	0.090	0.290	0.290	0.17	0.16	0.446	0.366
September	0.930	0.600	0.950	0.590	0.86	1.00	0.668	0.547
October	1.110	0.910	0.770	1.280	0.81	0.92	1.036	1.334
Average, 5 months—May-Sept.	0.568	0.404	0.580	0.690	0.52	0.76	0.693	0.644
Average, 6 months—May-Oct.	0.660	0.490	0.620	0.790	0.57	0.78	0.750	0.762
Average, 5 months—June-Oct.	0.682	0.474	0.606	0.866	0.62	0.89	0.670	0.676

TABLE X.

COMPARISON OF RAINFALL COLLECTED IN EASTERN STREAMS, SIX MONTHS—MAY, JUNE, JULY, AUGUST, SEPTEMBER AND OCTOBER, 1896.
PER CENT. COLLECTED.

	May.	June.	July.	August.	September.	October.	Average.
Cochituate	27.50	23.5	16.9	19.4	12.5	36.40	22.7
Sudbury	24.90	21.4	6.8	4.3	8.7	28.00	15.7
Mystic	38.50	31.9	16.2	12.9	13.5	27.50	23.6
Perkiomen	12.00	11.0	21.0	28.0	12.0	31.00	19.1
Neshaminy	13.00	9.0	20.0	21.0	16.0	35.00	19.0
Tohickon	10.00	4.0	32.0	11.0	19.0	40.00	19.3
Average	20.98	16.8	18.8	16.1	13.6	32.98	19.9

COMPARISON OF RAINFALL COLLECTED IN EASTERN STREAMS, SIX MONTHS—MAY, JUNE, JULY, AUGUST, SEPTEMBER AND OCTOBER, 1896.
PER CENT. COLLECTED (*Concluded*).

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.
May	27.5	24.9	38.5	12.0	13.0	10.0
June	23.5	21.4	31.9	11.0	9.0	4.0
July	16.9	6.8	16.2	21.0	20.0	32.0
August	19.4	4.3	12.9	28 0	21.0	11.0
September	12.5	8.8	13.5	12.0	16.0	19.0
October	36.4	28.0	27.5	31.0	35.0	40.0
Average, 5 months, May-September	19.9	13.2	22.6	16.8	16.0	15.2
Average, 6 months, May-October	22.7	15.7	23.6	19.1	19.0	19.3
Average, 5 months, June-October	21.7	13.8	20.4	20.6	20.2	21.2

TABLE XI.

Comparison of Eastern Streams. Flow in Cubic Feet per Second per Square Mile, Six Months—May, June, July, August, September and October, 1895.

	May.	June.	July.	August.	September.	October.	Summary.	Average.
Cochituate	0.84	0.36	0.480	0.435	0.620	1.710	4.440	.....
Sudbury	0.98	0.27	0.360	0.360	0.135	2.130	4.230	.....
Mystic	1.14	0.45	0.480	0.670	0.290	1.240	4.270	.....
Perkiomen	0.85	0.38	0.530	0.240	0.150	0.200	2.350	.....
Neshaminy	0.62	0.46	0.765	0.570	0.050	0.070	2.540	.....
Tohickon	0.57	0.24	0.700	0.310	0.040	0.080	1.940	.....
Average	0.83	0.36	0.550	0.430	0.214	0.905	3.289	0.548

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.	Merrimac.
May	0.840	0.980	1.140	0.85	0.620	0.570	0.47
June	0.360	0.270	0.450	0.38	0.460	0.240	0.69
July	0.480	0.360	0.480	0.53	0.760	0.700	0.60
August	0.438	0.360	0.670	0.24	0.580	0.310	0.47
September	0.620	0.135	0.290	0.15	0.050	0.040	0.43
October	1.710	2.130	1.240	0.20	0.070	0.080	0.92
Average for 5 months, May-September	0.550	0.42	0.610	0.43	0.490	0.370	0.530
Average for 6 months, May-October	0.740	0.71	0.710	0.39	0.420	0.320	0.600
Average for 5 months, June-October	0.721	0.65	0.626	0.30	0.385	0.274	0.622

TABLE XII.

COMPARISON OF RAINFALL COLLECTED IN EASTERN STREAMS, 1895. PER CENT. COLLECTED.

	May.	June.	July.	August.	September.	October.	Average.
Cochituate	47.8	13.0	11.8	12.6	25.0	20.6	21.8
Sudbury	56.1	10.8	8.2	9.9	6.7	23.0	19.1
Mystic	41.5	13.7	12.8	14.1	15.7	14.0	18.6
Perkiomen	28.0	12.0	15.0	8.0	18.0	7.0	14.6
Neshaminy	27.0	12.0	23.0	20.0	7.0	3.0	15.3
Tohickon	22.0	6.0	23.0	8.0	5.0	2.0	11.0
Average	37.1	11.2	15.6	12.1	12.9	11.6	13.4

COMPARISON OF RAINFALL IN EASTERN STREAMS, 1895. PER CENT. COLLECTED (*Concluded*).

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.
May	47.8	56.1	41.5	28.0	27.0	22.0
June	13.0	10.8	13.7	12.0	12.0	6.0
July	11.8	8.2	12.8	15.0	23.0	23.0
August	12.6	9.9	14.1	8.0	20.0	8.0
September	25.0	6.7	15.7	18.0	7.0	5.0
October	20.6	23.0	14.0	7.0	3.0	2.0
Average for 5 months, May-September	22.0	18.3	19.6	16.2	18.0	13.0
Average for 5 months, June-October	16.8	11.7	14.1	12.0	13.0	8.8
Average for 6 months, May-October	21.8	19.1	18.6	14.6	15.0	11.0

TABLE XIII.

Inches of Rainfall Collected, Average Year, 1895.

	May.	June.	July.	August.	September.	October.	Summary. Six months.	Average.
Cochituate	0.97	0.40	0.55	0.50	0.690	1.970	5.08	.....
Sudbury	1.13	0.30	0.41	0.41	0.150	2.460	4.86	.....
Mystic	1.31	0.50	0.55	0.77	0.320	1.430	4.88	.....
Average	1.14	0.40	0.50	0.56	0.386	1.953	4.94	0.823

Flow in Cubic Feet per Second per Square Mile, 1895.

	May.	June.	July.	August.	September.	October.	Summary. Six months.	Average.
Genesee	0.19	0.13	0.11	0.12	0.10	0.44	1.09	.....
Hudson	1.76	0.70	0.66	1.00	0.65	0 69	5.46	.....
Merrimac	0.47	0.69	0.60	0.47	0.43	0.92	3.58	.....
Connecticut	1 43	0.75	0.35	0.38	0.32	0.47	3.70	.....
Average	0.96	0.55	0.43	0.49	0.37	0.63	3.46	0.576

TABLE XIV.

COMPARISON OF EASTERN STREAMS. FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE, SIX MONTHS—MAY, JUNE, JULY, AUGUST, SEPTEMBER, OCTOBER, 1894.

	May.	June.	July.	August.	September	October.	Summary.	Average.
Cochituate	0.79	0.40	0.330	0.360	0.41	0.57	2.86	.....
Sudbury	1.30	0.65	0.250	0.320	0.23	0.58	3.33	.....
Mystic	1.14	0.82	0.430	0.330	0.32	0.50	3.54	.....
Perkiomen	5.78	1.01	0.500	0.300	1.50	1.44	10.53	.....
Neshaminy	6.42	0.95	0.370	0.295	2.03	1.29	11.35	.....
Tohickon	7.43	0.47	0.165	0.100	2.98	1.82	12.96	.....
Average	3.81	0.72	0.340	0.280	1.24	1.03	7.43	1.24

COMPARISON OF EASTERN STREAMS. FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE, SIX MONTHS—MAY, JUNE, JULY, AUGUST, SEPTEMBER, OCTOBER, 1894 (*Concluded*).

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.	Merrimac.
May	0.790	1.300	1.140	5.78	6.420	7.430	1.550
June	0.400	0.650	0.820	1.01	0.950	0.470	1.400
July	0.330	0.250	0.430	0.50	0.370	0.165	0.500
August	0.360	0.320	0.330	0.30	0.295	0.100	0.370
September	0.410	0.230	0.320	1.50	2.030	2.980	0.400
October	0.570	0.580	0.500	1.44	1.290	1.820	0.500
Average for 5 months, May-September	0.460	0.550	0.610	1.82	2.010	2.230	0.840
Average for 6 months, May-October	0.480	0.550	0.590	1.75	1.890	2.160	0.780
Average for 5 months, June-October	0.416	0.406	0.480	0.95	0.980	1.107	0.634

TABLE XV.

Comparison of Rainfall Collected in Eastern Streams, Six Months—May, June, July, August, September and October, 1894.

Per Cent. Collected.

	May.	June.	July.	August.	September.	October.	Average.
Cochituate	24.6	27.9	10.4	16.1	20.0	12.8	18.6
Sudbury	35.4	62.6	8.8	18.4	9.8	12.5	27.9
Mystic	25.3	125.8	14.2	15.1	14.3	10.5	33.9
Perkiomen	57.0	31.0	20.0	15.0	26.0	27.0	29.0
Neshaminy	55.0	41.0	11.0	13.0	28.0	28.0	29.0
Tohickon	63.0	20.0	8.0	6.0	35.0	41.0	29.0
Average	43.4	51.5	12.0	13.9	22.2	21.9	27.5

Comparison of Rainfall Collected in Eastern Streams, Six Months—May, June, July, August, September and October, 1894.

Per Cent. Collected (*Concluded*).

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.
May	24.6	35.4	25.3	57.0	55.0	63.0
June	27.9	62.6	125.8	31.0	41.0	20.0
July	10.4	8.8	14.2	20.0	11.0	8.0
August	16.1	18.4	15.1	15.0	13.0	6.0
September	20.0	9.8	14.3	26.0	28.0	35.0
October	12.8	12.5	10.5	27.0	28.0	41.0
Average for 5 months, May-September	19.8	27.0	38.9	30.0	29.0	26.0
Average for 6 months, May-October	18.6	27.9	34.2	29.0	29.0	29.0
Average for 6 months, June-October	17.4	22.4	36.0	24.0	24.0	22.0

TABLE XVI.

Flow in Cubic Feet per Second per Square Mile, 1894.

	May.	June.	July.	August.	September.	October.	Summary. Six months.	Average.
Genesee	4.43	1.10	0.14	0.22	0.93	0.44	7.26	.....
Hudson	1.94	1.76	0.81	0.63	0.47	0.94	6.55	.....
Merrimac	1.55	1.40	0.50	0.37	0.40	0.50	4.72	.....
Connecticut	1.26	1.00	0.44	0.27	0.31	0.53	3.81	.....
Average	2.29	1.31	0.49	0.37	0.53	0.60	5.58	0.93

Inches of Rainfall Collected, Dry Year, 1894.

	May.	June.	July.	August.	September.	October.	Summary. Six months.	Average.
Cochituate	0.910	0.450	0.380	0.410	0.460	0.660	3.27	.....
Sudbury	1.500	0.720	0.290	0.370	0.260	0.670	3.81	.....
Mystic	1.310	0.910	0.490	0.380	0.360	0.580	4.03	.....
Average	1.240	0.693	0.390	0.390	0.360	0.640	3.70	.....
Cubic feet per second	1.075	0.621	0.338	0.338	0.322	0.555	.....	.....

TABLE XVII.

COMPARISON OF EASTERN STREAMS. FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE, SIX MONTHS—MAY, JUNE, JULY, AUGUST, SEPTEMBER AND OCTOBER, 1888.

	May.	June.	July.	August.	September.	October.	Summary.	Average.
Cochituate	2.05	0.47	0.410	0.82	2.00	2.23	7.980	.....
Sudbury	2.52	0.66	0.180	0.59	1.78	3.09	8.820	.....
Mystic	2.49	0.76	0.340	0.47	1.17	2.37	7.600	.....
Perkiomen	0.80	0.34	0.220	1.32	3.29	1.09	7.060	.....
Neshaminy	0.45	0.20	0.135	0.56	2.35	0.91	4.600	.....
Tohickon	0.45	0.14	0.050	1.54	4.91	1.34	8.430	.....
Average	1.46	0.43	0.220	0.88	2.60	1.84	7.415	1.236

COMPARISON OF EASTERN STREAMS. FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE, SIX MONTHS—MAY, JUNE, JULY, AUGUST, SEPTEMBER AND OCTOBER, 1888 (*Concluded*).

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.	Merrimac.
May	2.05	2.52	2.49	0.80	0.45	0.450	5.10
June	0.47	0.66	0.76	0.34	0.20	0.140	1.40
July	0.41	0.18	0.34	0.22	0.13	0.050	0.53
August	0.82	0.59	0.47	1.32	0.56	1.540	0.57
September	2.00	1.78	1.17	3.29	2.35	4.910	1.69
October	2.23	3.09	2.37	1.09	0.91	1.340	2.95
Average, 5 months, May-September	1.15	1.14	1.04	1.19	0.74	1.420	1.86
Average, 6 months, May-October	1.33	1.47	1.27	1.18	0.76	1.405	2.04
Average, 5 months, June-October	1.19	1.26	1.02	1.25	0.83	1.590	1.43

TABLE XVIII.

COMPARISON OF RAINFALL COLLECTED IN EASTERN STREAMS, SIX MONTHS—MAY, JUNE, JULY, AUGUST, SEPTEMBER AND OCTOBER, 1888. PER CENT. COLLECTED.

	May.	June.	July.	August.	September.	October.	Average.
Cochituate	51.2	25.8	28.1	14.9	26.2	51.9	33.0
Sudbury	60.3	28.7	14.9	10.9	23.2	71.4	34.9
Mystic	56.5	38.1	17.5	8.8	15.3	55.3	31.9
Perkiomen	29.0	24.0	9.0	19.0	50.0	37.0	28.0
Neshaminy	18.0	9.0	4.0	11.0	38.0	28.0	18.0
Tohickon	17.0	9.0	2.0	22.0	66.0	38.0	26.0
Average	38.7	22.4	12.6	12.9	36.4	46.9	28.6

COMPARISON OF RAINFALL COLLECTED IN EASTERN STREAMS, SIX MONTHS—MAY, JUNE, JULY, AUGUST, SEPTEMBER AND OCTOBER, 1888. PER CENT. COLLECTED (*Concluded*).

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.
May	51.2	60.3	56.5	29.0	18.0	17.0
June	25.8	28.7	38.1	24.0	9.0	9.0
July	28.1	14.9	17.5	9.0	4.0	2.0
August	14.9	10.9	8.8	19.0	11.0	22.0
September	26.2	23.2	15.3	50.0	38.0	66.0
October	51.9	71.4	55.3	37.0	28.0	38.0
Average, 5 months, May-September	29.2	27.6	27.2	26.0	16.0	23.0
Average, 5 months, June-October	29.4	29.8	27.0	27.8	18.0	27.4
Average, 6 months, May-October	33.0	34.9	31.9	28.0	18.0	26.0

TABLE XIX.

Inches of Rainfall Collected, 1888.

	May.	June.	July.	August.	September.	October.	Summary. Six months.	Average.
Cochituate	2.37	0.530	0.470	0.940	2.31	2.57	9.19	.....
Sudbury	2.91	0.730	0.210	0.680	1.99	3.57	10.09	.....
Mystic	2.88	0.840	0.390	0.540	1.31	2.74	8.70	.....
Average	2.72	0.700	0.360	0.720	1.87	2.96	9.32	.....
Equivalent run-off	2.25	0.627	0.312	0.624	1.68	2.56	.....	.....

Flow in Cubic Feet per Second per Square Mile.

	May.	June.	July.	August.	September.	October.	Summary. Six months.	Average.
Merrimac	5.10	1.40	0.53	0.57	1.69	2.95	12.24	.....
Blackstone (Uxbridge)	3.09	1.92	1.25	1.89	1.84	2.54	12.53	.....
Charles River (Watertown)	3.23	1.62	0.55	1.86	1.65	3.24	11.15	.....
Mother Brook (East Dedham)	1.78	0.83	0.36	0.38	0.77	1.81	5.93	.....
Nashua River	2.30	1.32	1.28	1.33	2.33	4.82	13.38	.....
Average	3.16	1.41	0.79	1.00	1.65	3.07	11.05	1.84

TABLE XX.

COMPARISON OF FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE OF EASTERN STREAMS IN WET AND DRY YEARS.

Dry Years.

Average flow of streams, five months, May to September, dry seasons.. 0.567
This would be a safe development of a stream.
Average flow of streams, dry years..... 1.290
Average flow of streams, five months, May to September, wet seasons.. 1.435
Average flow of streams, wet years..... 2.095

Note uniformity of flow of streams per square mile, irrespective of area of watershed. Also that five months' flow in wet seasons is at greater rate than yearly flow in dry years.

An average of the dry seasons' flow = 0.567; an average of the wet seasons' flow = 1.435; equal to 1, would represent the maximum safe development of a stream for power and manufacturing purposes, with an expectation of shutting down for two or three months in the dry season and installing auxiliary steam power.

TABLE XXI.

Month by per cent. of collection.	Month and number of days.	Average rainfall 1818-1897.	Average per cent. of collection.	Depth in inches of collection.	Equivalent run-off in cu. ft. per sec. per sq. mile.	
1	Aug. 30	4.35	21.3	0.9265	0.855	
2	July 31	3.68	21.8	0.8022	0.695	
3	Sept. 30	3.52	28.3	0.9960	0.895	0.808 average flow for 3 driest months.
4	Oct. 31	3.90	29.3	1.1430	0.990	
5	Nov. 30	4.30	36.5	1.5690	1.410	0.965 average flow for 5 driest months.
6	June 30	3.22	44.8	1.4420	1.290	1.019 average flow for 6 driest months.
7	Dec. 31	3.89	60.7	2.3710	2.060	
8	May 31	3.80	65.8	2.5000	2.170	
9	Jan. 31	3.95	76.3	3.0140	2.610	
10	Mar. 31	4.30	78.8	3.3880	2.940	
11	Feb. 28	3.80	132.2	5.0240	4.820	
12	April 30	3.98	145.0	5.7700	5.180	0.216 average flow per year.

Thus corroborating that one cubic foot per second per square mile is the maximum safe development of a New England stream for manufacturing purposes.

TABLE XXII.

Greatest and Least Flow of Streams.

River.	Place.	Drainage area, sq. miles.	Extremes of Flow. Maximum cubic ft. per sec.	Extremes of Flow. Minimum cubic ft. per sec.	Maximum cubic ft. per sec. per sq. mile.	Minimum cubic ft. per sq. mile.	Mean.	Authority and Remarks.
	New England							
Merrimac	Lawrence	4,509.00	96,000	1,400.000	20.87	0.310	2.19	Lakes and artificial reservoirs. Wooded.
Concord	Lowell	361.00	4,449	59.840	12.32	0.170	1.39	C. Herschel. Stream sluggish and swampy. Few woods. Hilly and rolling. Some reservoirs.
Sudbury	Framingham	78.00	3,228	2.800	41.38	0.036	1.67	A. Fteley. Hilly and swampy. ⅙ to ⅛ wooded.
Connecticut	Hartford	10,234.00	207,443	5,219.000	20.27	0.510	1.86	T. G. Ellis. Numerous lakes and artificial reservoirs. Wooded. Mountainous in parts.
Cochituate		1.90	. . .	. . .	. . .	.020	1.49	
Housatonic		790.00	. . .	130.000	. . .	0.165	. . .	H. Loomis. Report, N. Y. Committee Public Works, 1879.
	New York.							
Croton		338.82	25,367	50.800	74.87	0.150	1.65	J. J. R. Croes and G. W. Howell.
Croton (west branch)		20.37	1,109	0.407	54.44	0.020	. . .	J. J. R. Croes. Very broken and undulatory.
	New Jersey.							
Ramapo	Pompton	159.50	10,540	22.500	66.10	0.140	1.73	Minimum, October, 1892.
Pequannock	Pompton	84.00	4,460	. . .	48.90	. . .	. . .	
Pequannock	Macopin Int'ke	62.60	. . .	8.000	. . .	0.130	. . .	Clemens Herschel. October, 1875.
Rockaway	Dover	52.20	2,250	. . .	43.00	. . .	. . .	
Passaic	Paterson	796.90	19,105	150.000	24.20	0.190	2.58	L. B. Ward. September, 1883. This flow is occasionally not exceeded for more than two weeks.
Hackensack	New Milford	114.80	. . .	21.700	. . .	0.190	. . .	C. B. Brush.
Raritan	Bound Brook	879.00	52,000	180.000	59.30	0.200	1.72	Minimum by Ashbel Welch.
Raritan	Bound Brook	879.00	. . .	122.000	. . .	0.140	. . .	October 13th-19th, 1892. C. C. V.
Delaware	Stockton	6,790.00	254,643	1,179.000	37.50	0.170	. . .	Minimum, September, 1881.

TABLE XXII (*Concluded*).

Greatest and Least Flow of Streams.

River.	Place.	Drainage area, sq. miles.	Extremes of Flow.		Maximum cubic ft. per sec. per sq. mile	Minimum cubic ft. per sq. mile.	Mean.	Authority and Remarks.
			Maximum cubic ft. per sec.	Minimum cubic ft. per sec.				
	New Jersey.							
Musconetcong . .	Finesville . .	155.80	1,960	. . .	12.80	0.3900	1.14	
Paulinskill	Hainesburg . .	174.80	4,126	29.00	23.00	0.1700	1.69	Least in 1890.
Pequest	Townsbury . .	83.40	800	14.00	9.60	0.1700	. . .	Minimum from run of mill.
Great Egg Harbor .	May's Landing	215.80	4,756	59.00	22.00	0.2700	. . .	
	Pennsylvania.							
Tohickon	Pt. Pleasant . .	102.20	5,546	0.21	54.30	0.0010	1.97	Annual reports of Chief Engineer of Philadelphia Water Department.
Neshaminy	Forks	139.30	5,767	1.26	41.40	0.0090	1.60	
Perkiomen	Frederick . .	152.00	5,305	7.56	34.90	0.0500	1.58	
Schuylkill	Philadelphia .	1,800.00	. . .	307. to 378.00	. . .	0.17 to 0.2100	. . .	E. F. Smith and H. P. M. Kirkinbine. Hilly and rolling. No lakes. Some reservoirs.
Ohio	Pittsburg . . .	19,000.00	. . .	2,271.00	6.17	0.1140	2.12	J. H. Harlow. Hilly and mountainous. No lakes. Wooded.
	Southern.							
Potomac	Dam No. 5. .	4,640.00	92,772	363.00	22.15	0.0783	. . .	Quoted by W. R. Hutton. Narrow valleys. Steep slopes. Wooded. No lakes.
Potomac	Great Falls . .	11,476.00	175,000	1,063.00	15.25	0.0930	1.85	W. R. Hutton. Country more open. No lakes.
Kanawha	Charleston Pool	8,900.00	120,000	1,100.00	13.49	0.1230	. . .	Gill, Scott and Hutton. Mountainous. Steep. No lakes. Wooded.
	Western.							
East Carson	. . . . .	41.40	. . .	. . .	10.26	0.7000	1.78	
West Carson . . .	. . . . .	7.00	. . .	. . .	18.34	0.5000	2.38	
Rio Grande	Del Norte, Cal.	1400.00	. . .	. . .	4.24	0.1400	0.80	

The average annual rainfall in Colorado is about 15 inches. This refers, of course, to the average of the whole State, valleys as well as mountain watersheds and table-lands.

It is a well-known fact in general that the amount of rain increases with the elevation above the sea level, up to a maximum plane, above which a decrease takes place, and empirical formulæ have been deduced for determining such proportions. The elevation at which the maximum rainfall is precipitated is, according to the observed law of decrease in temperatures, at that point at which the prevailing winds are cooled to just below their dew point.

Tables covering this subject are given in Report of the Geological Survey, No. 140, pages 328-329, etc., reference being made to the report of Prof. G. E. Curtis, Washington, 1884, Pamphlet XVI, Signal Service Notes.

Mr. Fellows, of the United States Hydrographic Office, stationed at Denver, Col., gave me as his opinion that the average rainfall on the San Miguel and Dolores watersheds was 18 inches. I have, however, assumed that the average precipitation upon the higher mountain sides and foothills, composing the larger part of the Beaver and Naturita watersheds, was 26 inches, for the following reasons, in addition to the statements above:

	Inches.
At Telluride, which has an elevation of 8756 feet, the average rainfall for fourteen years is	28.17
At Rico, elevation 8758 feet, average rainfall for twenty-eight years is	29.58
At Pikes Peak, elevation 14,134 feet, rainfall	28.65
At Summit, elevation 11,300 feet, average rainfall	29.00
At Fort Lewis, elevation 8500 feet, average rainfall	17.19
At Fort Garland, elevation 7937 feet, average rainfall	12.74
At Saguache, elevation 7740 feet, average rainfall	42.60
Grand average	26.85

At Ruby, which has an elevation of 10,000 feet, the average rainfall for—

	Inches.
1898	17.00
1899	44.97
1900	17.86
1901	29.12

An average of 27.26 inches for these four years. These four years, however, represent about 10 per cent. above the normal precipitation throughout Colorado. Therefore, deducting 10 per cent., the average rainfall at Ruby for the four years on the normal basis would be 24.53 inches.

I also append hereto the monthly rainfall for 1901, month by

month, at Telluride, which is in San Miguel County, and for 1900 and 1901, at Ruby, which is in Ouray County, and which is the nearest next available high elevation station, substituting an average amount for the two months omitted in the report:

	Rainfall at Ruby. Elevation 10,000 ft. Inches. 1900.	Inches. 1901.	Rainfall at Telluride. Elevation 8756 ft. Inches. 1901.
January	1.73	4.12	1.30
February	1.25	4.06	1.36
March	1.43	5.41	1.98
April	3.10	..	2.27
May	0.10	3.55	1.55
June	0.43	1.00	1.56
July	0.20	0.08	0.82
August	1.60	1.47	3.77
September	2.00	0.42	0.15
October	2.95	1.81	0.77
November	..	1.60	1.25
December	1.17	2.60	2.28
	15.86	26.12	19.06
Average Nov.	2.00	April 3.00	..
	17.86	29.12	19.06

And also a table giving the rainfall at Telluride, which is the only station from which reports have been made from June, 1901, to May, 1902, inclusive, substituting February and March of 1901 for the corresponding two months of 1902, for which months no returns were made:

RAINFALL AT TELLURIDE FROM JUNE, 1901, TO MAY, 1902.

June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.
1.56	.82	3.77	.15	.77	1.25	2.28	1.05	1.36	1.98	.54	2.83

The average for the composite year so applied is 15.3 inches, which is about 54 per cent. of the average Telluride rainfall. Therefore, the amount of water present and available this year in the Beaver and Naturita Creeks may be safely taken as being at least 50 per cent. below what might otherwise have been expected.

I give below two tables, one of the normal and monthly precipitation at Breckenridge, Summit County, and one at Rico, Dolores County, Col.:

BRECKENRIDGE, SUMMIT COUNTY—ELEVATION 9524 FEET.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	1.92	3.88	3.60	3.33	2.61	0.94	2.79	2.02	1.20	1.47	3.00	3.10	29.86
1895	3.29	2.31	2.37	1.88	4.39	1.81	2.43	3.62	1.11	1.95	1.76	2.67	55.59
1896	1.88	1.89	4.83	0.60	1.47	0.30	3.10	2.29	2.25	0.82	3.87	0.73	24.03
1897	2.90	1.99	3.53	4.00	1.54	1.53	1.30	2.27	1.16	1.02	0.60	2.25	24.49
1898	0.29	0.59	1.16	1.53	0.46	1.14	2.19	1.59	0.28	1.53	4.09	1.34	16.29

RICO, DOLORES COUNTY—ELEVATION 8737 FEET.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	2.78	4.25	3.34	1.21	2.09	0.68	2.58	2.27	2.55	1.08	1.03	2.58	26.44
1895	7.20	3.03	1.81	0.33	1.76	1.58	2.97	3.60	1.33	0.20	. .	2.75	. . .
1896	2.40	1.40	2.10	1.20	0.35	0.59	4.13	2.32	4.46	2.20	2.40	1.70	25.25
1897	3.26	5.60	6.40	1.66	4.15	0.98	2.41	. .	5.80	2.82	1.60	2.02	. . .
1898	3.10	1.35	3.80	2.62	3.82	1.60	3.10	4.13	0.88	0.15	0.85	. .	. . .

RUN-OFF.

We now come to the next most important question, which is that of run-off, or the proportion of rainfall which finally finds its way to the stream. Mr. Fellows, of the State Engineer's Office, advises me that the run-off from 1895 to 1899, from April to November, inclusive, for the section under consideration, amounted to but 7.12 inches, which would be 39.6 per cent. of the rainfall, which he also gave me.

The report of the United States Geological Survey for 1898 gives the run-off of the San Miguel River for the year 1897 as a total of 10.09 inches, equal to an average of .74 cubic foot per second per square mile, a copy of which table is given on following page:

DRAINAGE AREA OF SAN MIGUEL RIVER.

327 square miles.

Run-off for 1897.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Depth in inches	.21	.19	.21	2.20	2.20	2.64	1.33	.64	.73	.64	.32	.26
*Sec. ft. per sq. mile	.18	.18	.18	0.65	1.91	2.37	1.15	.56	.66	.56	.29	.23

Total run-off in inches, 10.09. Average run-off, .74 second feet per square mile.

I also give below a table of the discharge of the San Miguel River from the same point of observation, Seymour, otherwise known as the mouth of Fall Creek, Col., which gives the discharge in cubic feet per second, and also the run-off in inches and in cubic feet per second per square mile for the last six months of 1899:

ESTIMATED DISCHARGE OF SAN MIGUEL RIVER AT SEYMOUR, COL.

Drainage Area, 327 square miles.

	Discharge in second ft.				Run-off.	
1895.	Maximum.	Minimum.	Mean.	Total for month in acre-feet.	Depth in inches.	Second ft. per sq. mi.
July	675	219	347	21,336	1.22	1.06
August	312	145	230	14,142	0.81	0.70
September	168	61	100	5,950	0.35	0.31
October	101	42	64	3,935	0.23	0.20
November	180	..	30	1,785	0.11	0.10
December	..	..	10	615	0.03	0.03

*Sec. ft. = cubic feet per second.

1898.	Discharge in second ft. Maximum.	Minimum.	Mean.	Total for month in acre-feet.	Run-off. Depth in inches.	Second ft. per sq. mi.
April, 11-30...	..	..	272	16,185	0.92	0.83
May	545	196	296	18,200	1.04	0.90
June	1335	571	813	48,377	2.79	2.49
July	760	109	380	23,365	1.34	1.16
August	183	109	133	8,178	0.47	0.41
September	121	66	89	5,296	0.30	0.27
October	66	30	50	3,074	0.17	0.15
November	66	22	40	2,380	0.13	0.12
1899.						
April	299	25	134	7,974	0.41	0.46
May	934	126	414	25,456	1.27	1.46
June	995	249	538	32,013	1.65	1.84
July	387	176	238	14,634	0.73	0.84
August	387	105	195	11,990	0.60	0.69
September	138	64	101	6,002	0.31	0.35

As the year 1895 was rather a dry year, and the year 1897 was a notoriously wet year, these measurements may fairly represent the maximum and mean run-off measurements of the San Miguel, although having a much larger area (327 square miles) than either the Beaver Creek, with 88 square miles, or the Naturita Creek, with 53 square miles, and as all of these streams have a common source of supply from the San Miguel and Dolores Mountains, the percentages obtained from one and the run-off in cubic feet per second per square mile may be fairly applicable to the other.

To demonstrate the mean and maximum discharge that may be obtained in this section I append a table, giving the mean discharge in cubic feet per second for May, June and July of the years 1895, 1896, 1897, 1898 and 1899:

MEAN DISCHARGE OF SAN MIGUEL RIVER IN CUBIC FEET PER SECOND.

	May.	June.	July.
1895	....	556	341
1896	770	349	157
1897	627	774	375
1898	296	813	380
1899	416	538	238
	2109	3030	1491
	527	606	298
	606		
	298		
	1431		

Average = 477 ÷ 327 square miles = 1.458 cubic feet per second per square mile

which shows that June gives the highest average discharge, and also that the average discharge for the three months' period for five years is 1.458 cubic feet per second per square mile.

It also shows that the three months' discharge of 1897 was 35 per cent. greater than the average three months' discharge of 1896, 1898 and 1899, proving conclusively the relation that the year 1897 bears to the other years. The maximum discharge, which was found on June 16, 1897, is 3.05 cubic feet per second per square mile, and may be safely taken as the maximum discharge per square mile of any stream in this immediate vicinity.

DISCUSSION.

Mr. Charles T. Main.—I have not had sufficient time to prepare any extended discussion of Mr. Webber's paper, but would like to say a few words on one point only which is discussed in the paper, viz., the economical development of a water power.

Mr. Webber has stated that about 1 cubic foot per second per square mile is the maximum commercial development, or the flow which corresponds to about the sixth month of an average year.

In a very large number of plants which I have examined, fully 90 per cent. have been developed to use all the water from six to seven months of an average year, and a large part of these plants have been installed without any particular engineering skill, the size being based upon the horse sense, one might say, of the owners. This is at variance with the very frequent testimony which we hear that the proper size of the development is one which will use all the water for at least nine months of an average year, and sometimes the statement is made that the economical limit is eleven months, with water wasting for only one month.

For the average power used for manufacturing purposes, say ten hours a day, a six to seven months' development is more nearly correct than eleven months, but no general statement can be made to cover all cases. It is simply a question of economics, which requires solving for each particular case.

The factors which enter into the problem are, on one side, the cost of the water-power development and the fixed charges on the same, if nothing is paid for the water, and, on the other side, the saving which can be affected by the use of such plant.

The cost of the dam will be a constant for any size development of wheels, all other conditions being the same. The headgates, canal, racks, feeders, wheels, wheel pits and tailraces must be increased in size and cost for the purpose of using a larger amount of water than the flow in the average month or sixth month of an

average year, and the fixed charges for such increase in cost represent the annual cost of the corresponding increase in water power.

The saving due to such increase in water power is represented by the saving in coal only on the supplementary steam plant, necessarily run with such a varying water power, plus the cost of attendance on steam plant, if it can be shut down entirely during the months of maximum power on the wheels. As the water power is increased in size to use water for a greater number of months, the cost of such increase for each additional month makes a saving for a less number of months, and there comes a time when the saving on steam power is less than the fixed charges on the additional cost of water-power plant. Where these two items balance depends upon the following conditions:

(1) Cost of water-power plant for each increment of power.

(2) Saving affected by the decreased use of steam power, which would be very much more if the power is used twenty-four hours than if used for ten hours, and much more if by such an increase in the water-power plant it is possible to shut off all steam power.

An example will suffice to make this clear. Supposing the cost for each additional horse power of water-power plant required to use all the water for a longer period was $60 a horse power. The fixed charges on this, including interest, will be not less than 8 per cent., or $4.80 per year. The cost of coal and attendance on a steam plant, of say 500 horse power, with coal at $4 a ton, is about $13 a year per horse power, or $1.08 per month. $4.80 ÷ $1.08 = 4.44 months. In other words it would not pay to develop such a power to use all the water for more than about seven and one-half months.

If the engine or boilers cannot be shut down at all, a less saving could be made and the power could be economically developed for a less period than seven months.

The various conditions and lengths of time required to have the saving equal the fixed charges are shown on the following plate. This diagram is figured on coal at $4 per ton. Similar ones could be made for any other prices.

To use the diagram, supposing the water-power plant cost $50 per horse power and the size of steam plant is 200 horse power, on the ordinates find $50, cost of water-power plant. Run along horizontally until this line intersects the vertical line of 200 horse power of steam plant, and these two lines will be found to intersect about on the curve marked three months.

If the water-power plant cost $70 and the steam plant were

350 horse power, the time is five months during which water should waste.

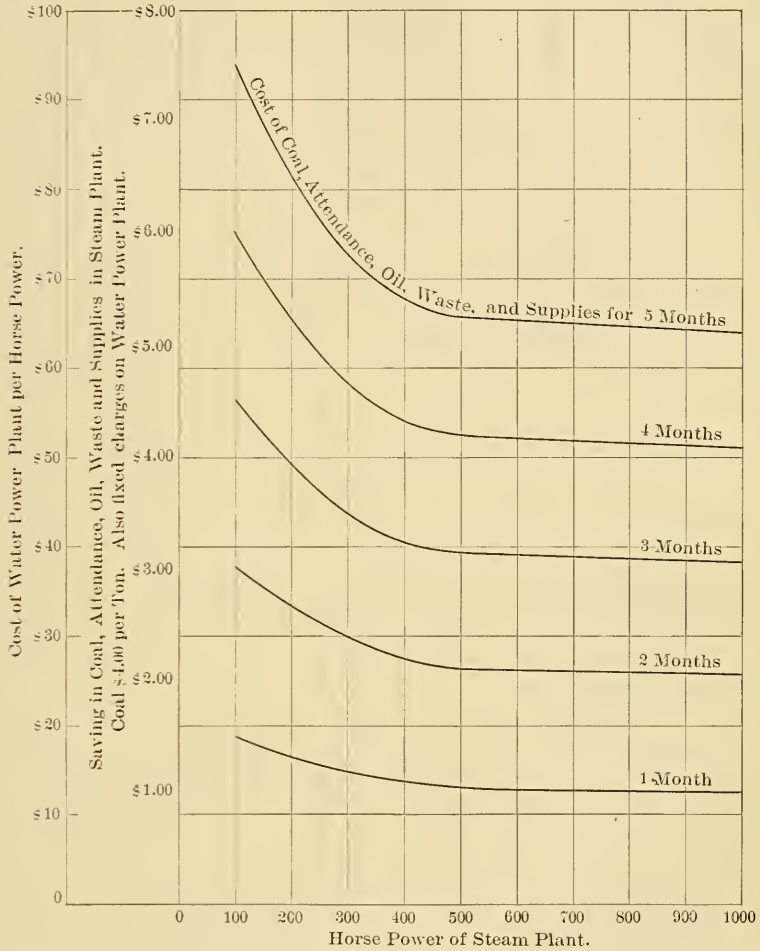


Diagram Showing Number of Months when water should be allowed to Waste with different sizes of Steam Plants and different Costs of Water Power.

Mr. Richard A. Hale.—In regard to the development of power on a stream very much depends on circumstances, but, in general, the sixth or seventh month would be the maximum amount to which a stream should be developed, and beyond that point much would depend on the local conditions and use of power required, depending on the amount of steam power used in connection with the plant.

In regard to the yield of streams the tables presented by Mr.

Webber are very interesting. The minimum flow on the Merrimac, he states, is .31 cubic foot per second per square mile. In the year 1883, which was an exceedingly dry year, the minimum yield for one week was .27 cubic foot per second per square mile, and in the year 1900 it was about the same amount. The minimum weekly yield, in general, during an average year, will seldom fall below .3 cubic foot per second per square mile. This yield is for twenty-four hours flow for a week of seven days. Owing to the water being used principally during the five and a half days of each week and stored Saturday afternoon and Sunday, the average flow for one week shows the yield of the river nearer the truth than for one day, when the water may be held back for storage or a large amount sent down from the accumulation of storage in ponds in the upper reaches of the river. The drainage area of the Merrimac River is 4450 square miles, and the measurements of the flow of the river are computed at Lawrence from daily observations. The results are published in the yearly report of the United States Geological Survey in the Hydrographic Department. The accuracy of the measurements is probably within 3 per cent. of the truth. The error may reach 5 per cent., and perhaps somewhat more with unusual conditions of ice in the river and broken flashboards.

In comparison with smaller drainage areas it is interesting to observe how much lower yield is obtained during the dry months from the smaller area.

In 1880 to 1883 the writer had occasion to measure the flow of the Shawsheen River at Andover, Mass. Daily measurements were made during this period, but the results have not been published, owing to anticipated lawsuits at that time. I may state, however, that the lowest yield during the driest week was .10 cubic foot per second per square mile, from a drainage area of 70 square miles. During the same period, the yield from the Merrimac River watershed was .27 cubic foot per second per square mile. On the Spicket River, at Lawrence, the writer has been making some measurements during the last two years, and during the early part of October of the present year the yield for a period of two weeks was somewhat less than .10 cubic foot per second per square mile from a drainage area of 68 square miles.

It is an interesting fact to notice on a large stream and large watershed that the amounts from small streams, as tributaries, are extremely low, and in some cases almost nothing. The yield of the large river reaches a certain point and does not fall below that point, being supplied from the subterranean reservoirs at a lower level than the smaller streams.

The yield of the Shawsheen River in an ordinary year during the driest week is .16 cubic foot per second per square mile, while the yield of the Merrimac River during a similar period is .32 cubic foot per second per square mile.

In connection with the investigations of the flow of the Charles River by the writer for the Charles River Dam Commission, some interesting facts were ascertained. During the dry period of the year 1900, at the Boston Manufacturing Company, at Waltham, there was a period of three weeks when the water wheels were not run on account of lack of water, and the leakage through the wheel gates could not supply enough water for the use of the bleachery below without taking off flashboards from the Boston Manufacturing Company's dam. This yield indicated from .10 to .15 cubic foot per second per square mile. This drainage area was about 163 square miles. There was no doubt large evaporation at this period from the ponds above the various dams.

It is gratifying to know that the State Board of Health is keeping a record of the flow of the Charles River at Watertown, and important information in regard to the flow will be obtained.

Prof. Dwight Porter.—Fair consideration of the run-off data which have thus far been obtained warns the engineer against expecting too high a degree of accuracy in estimates of flow based upon drainage area, rainfall and the observed discharge of certain standard streams, such as the Sudbury. And yet time has confirmed the writer's opinion that this method, if intelligently used, will often give results entitled to great confidence.

He has often felt, with Mr. Webber, that the Sudbury has been made to carry too heavy a load of responsibility in serving as a standard for so many streams as have been referred to it, but this seems excusable, since perhaps no other stream has been so closely or for so long a time observed. If there were others that had been studied with equal skill and thoroughness, they would no doubt receive equal weight, and we should be in better position than we are for making estimates in new cases.

Our dearth of information will be overcome in time, as data accumulate, and especially as other engineers follow Mr. Webber's example and put the facts in print where we all may benefit by them. Our members may not all know that the United States Geological Survey is attempting to gather and publish such data on a very extensive scale. It has in operation a large number of permanent gauging stations in various parts of the country, and in its annual reports for the past few years and in the bulletins issued under the title of Water Supply and Irrigation Papers will be found the results

of the gaugings, as well as many discharge records furnished by water-power and mill companies.

In considering estimates in damage cases it is apparent that engineers differ, not only in regard to the actual cubic feet per second to credit to streams in question for different parts of the year, but also as to how far, if at all, above the minimum the flow shall be classed as having practical value for power. Some are disposed to include the average flow for the year in their valuation, or even a part of what might be classed as freshet flow, while others admit but scant value in water power, and are inclined to credit a stream with little more than its minimum flow. Between these extremes there appears to the writer to be a proper line, not necessarily determined by average June flow or with reference to the five driest months, but depending upon the circumstances of each case, marking the limit beyond which it is simply uneconomical to instal turbines which must be largely duplicated in engines and will be for much of the time either idle or running inefficiently.

So far as concerns the scientific computation of the varying yield of a watershed for different proportions of the year, the difficulties encountered are of several kinds. The more simple data involved are the drainage area, amount of rainfall and run-off for the standard basin and the drainage area and rainfall for the stream under estimate. Of these the drainage area can probably be determined with the most accuracy, but unless there are maps at least as good as those of the Geological Survey, errors of several per cent. seem likely. The average rainfall over such a watershed as the Sudbury is perhaps known very closely, but that can scarcely be said of the Connecticut, or the Merrimac, or the Kennebec, or of any other stream draining much unsettled country, since in the higher and less-settled regions there are but few rainfall stations, and these are likely to be conducted by unskilled and inconstant observers, whose records display many gaps. The actual run-off from the Sudbury basin may be known within a very few per cent. of the truth, but can we put equal confidence in figures for the Connecticut for past years, the Kennebec or even the Merrimac in high stages? Even were these data unimpeachable, there still remains the difficult problem of referring to the standard basin the one in question and recognizing the points in which they are alike in geology, topography and climate and the points in which they differ, and of not only recognizing these, but assigning numerical values to them. Under these circumstances are we not forced to admit a considerable probable error in the result?

There seem to be two saving factors. Errors of a few per

cent. in such computations would seldom occasion much concern; and, further, the estimates which are made will probably never be fully checked. If one estimate the average flow of a stream at 400 cubic feet per second when he should have called it 300, who is going to find it out, since careful and continuous observations for a series of years would be needed to establish the truth? It is unfortunate that this is so, since greater certainty of a check would lead to greater care in estimating.

In studying the records of our northern streams with reference to their percentage of yield there are certain opportunities for error, which the writer thinks are liable to be overlooked. It is natural to study these records by calendar years, beginning January 1st and ending December 31st. But if, on January 1, 1903, there were, on a New Hampshire or Maine river basin, 20 or 30 inches of snow which had fallen in the previous calendar year, and on December 31, 1903, little or no snow, the stream would have received in the meantime a considerable amount of water which had no connection with the current precipitation of the year. The same thing would be true if the storage reservoirs were drawn lower by the end of the year than they stood at its beginning, and yet we seldom have the means of correcting the gross run-off from watersheds for the sources of error above mentioned. Still, again, in comparisons of different basins it is important to regard their different percentages of water surface, or we may be drawn into serious error in our conclusions.

To take a somewhat extreme example, data in the writer's possession indicate that the Winnepesaukee Lake basin supplied at the outlet dam, in 1885, the equivalent of about 31 per cent. of the rainfall for that year on that basin, including the lake surface; but if we correct the figures for the difference in lake level between the beginning and end of the year, the percentage of yield changes from 31 to 40. If we next allow for the fact that the lake probably received a little more during the year from rain falling upon its own surface than it lost by evaporation, we get the amount which presumably flowed into the lake from that portion of the drainage basin exterior to its own surface, and for that area the percentage run-off appears to be 49 per cent. But this exterior portion of the basin contains considerable lake and pond surface, probably amounting to as much as 8 per cent., and if we now apply, as before, a correction for the probable difference between rainfall and evaporation on this 8 per cent., we find our percentage of yield to rainfall for the remaining land surface to be as high as 53 per cent. But even this may not be right, for there is no means of knowing how the snow

depth over the basin compared at the beginning and end of the year, or how the storage in the lakes and ponds comprising the 8 per cent. of water surface compared at the beginning and end of the year. Similar difficulties confront one in a detailed study of many basins. The errors which have been indicated tend to disappear, as we neglect single calendar years and embrace periods of several years in our computations, for in this averaging process the effect of irregularities of snow and lake storage becomes relatively less and less.

It seems doubtful whether much of positive value comes from studying percentage relations between yield and rainfall for individual months, inasmuch as there seems to be no close connection between the two in so short a time. Thus, by Table II, in May, 1873, the flow of the Connecticut appears to have been 217 per cent. of the rainfall for that month. Obviously, the flow of the stream was derived only in small part from the May rainfall, and would have continued in large volume even had there not been a drop of rain in May. Even in so large a period as a year, the stream flow must be considerably dependent upon the condition of ground water established in the previous year, or perhaps further back; nevertheless, the general relation between the run-off and rainfall is the more accurately seen as the period considered increases.

To the writer the study of run-off statistics is very confusing and tedious, if confined to figures, and he believes that much may be gained in the drawing of conclusions by plotting such data whenever possible, and so presenting them graphically.

Mr. Freeman C. Coffin.—Such papers as this of Mr. Webber's, giving records of stream flow, are very valuable to the hydraulic engineer.

I would like to emphasize what he says about the necessity of taking into consideration the condition of the watershed in connection with its area and the amount of rainfall. The Sudbury River has been spoken of, and we recognize the great value of the long series of measurements of its flow that have been taken. Their value lies in the length of time and the accuracy with which they have been made. They can be used, with the exercise of judgment, in watersheds on which the conditions differ. I made measurements on a river in the southeastern part of this State for four years. These show a larger flow per square mile during the summer seasons than the Sudbury, largely, I believe, on account of the local character of the ground, which is mainly level and largely composed of sand or gravel, which acts, to a certain extent, as a storage reservoir, and this question of underground storage is just as im-

portant in consideration of the distribution of the run-off and flow of streams as the visible storage of lakes or ponds. It does not effect the total or average run-off. We find that in the same section of the country this is very much the same for all streams.

The distribution of the run-off is greatly affected by the underground storage, being larger in dry seasons and smaller in wet seasons, when the storage is considerable.

In regard to the effect of the rainfall the amount of the flow or yield depends upon the rainfall, but the percentage varies greatly with the different seasons, and Professor Porter's statement that the yield of any month cannot be determined by the rainfall of that month alone is very true, and, in considering the rainfall, it is just as important to take that of the preceding month, and even the month before that, into consideration as the rainfall of the month itself. For instance, in a case where it was desirable to deduce the amount of the flow from the rainfall of a certain watershed in this State, and where actual measurements were not available at that time, I applied the Sudbury River run-off to the watershed in question, using months of like rainfall on the Sudbury to the month under consideration, selecting those in which the rainfall of the preceding month was also similar to that of those preceding the month in question, and made an estimate, which turned out (after the actual run-off, as determined by the engineers on the other side by weir measurements, was known) to be within 2 or 3 per cent. of the amount, which was a much closer estimate than I had hoped to make. The closeness of the result may have been a mere coincidence, but it shows that a fair approximation can be obtained by the use of the Sudbury records, when careful consideration is given to the varying conditions.

In making estimates of water power it is quite customary to use averages, and in some relations they are useful, and in others, very misleading. The average run-off in October and November is low, while the average in January is fairly high. In a case with which I was recently connected it was estimated that the filling of a large storage reservoir caused the mill owners below much damage, on account of the retention of the water required to fill it. The reservoir was filled during the months of October, November and December, 1895, and January, 1896, and upon looking up the data, using the Sudbury River run-off, I found that the flow of October, November and December was much greater than the average, and thus while the reservoir was filling, the flow in the main river was far in excess of the wheel capacity of the mills, and therefore the diversion of the water required to fill the reservoir caused no loss

of power. In January alone was there any shortage; so that, based upon averages, there would be a loss to the mill owners. When the particular year was considered, there was no actual loss.

Regarding the figures of the flow of the Manhan River, referred to by Mr. Webber, which were taken by Mr. Tighe, City Engineer of Holyoke, the yield is given of every day in the year, which makes these tables of very great value, as they give, not only the average daily flow for the months, but the maximum and minimum daily flow.

There is one set of conditions from which very little data of flow have been collected, those pertaining to the streams of northeasterly New England and the Canadian provinces, which are icebound in winter. I know of very few instances of reported flow of these rivers, and these records cover but a short period of time. It will be of great value to the profession when the records of such streams are more complete. It is probable that the flow of January, February and March would be very different from that in Massachusetts or the Sudbury flow during the same months. In that part of the country the rain during these months is in the form of snow; many of the small brooks are frozen completely and the winter flow is small compared with that in places with higher temperature.

Mr. Main.—Mr. Coffin spoke of the desirability of getting some records of streams which are icebound in the winter.

The St. Croix River, at Taylor's Falls, was gauged by the U. S. Engineers during December of 1881 and eleven months of 1882. Below are given the results of these measurements, and opposite the gaugings is given the rainfall as recorded by the U. S. Weather Bureau in St. Paul for the corresponding months.

About a year and a half ago daily gaugings were begun and have since been continued for parties who are interested. These records will soon be of value.

The area of the watershed at Taylor's Falls is about 5950 square miles.

Rainfall and Run-off.

Month.	Rainfall in inches.	Run-off in cubic feet per second.
1881.		
November	1.36	..
December	0.53	3,500
1882.		
January	0.67	2,700
February	2.35	3,400
March	3.25	4,100
April	1.61	16,100
May	2.44	15,700
June	2.68	9,700

Month. 1882.	Rainfall in inches.	Run-off in cubic feet per second.
July	2.84	9,900
August	2.45	5,200
September	0.27	3,800
October	1.99	6,300
November	1.61	4,800
Average		7,100

The recent gaugings are being plotted together with the temperature of the atmosphere on the same sheet. It is interesting to see how the rise of temperature is followed soon by a rise of flow.

Mr. Lewis M. Hastings.—While it is self-evident that the amount of rainfall on a given catchment area must have an important influence on the run-off from that area, yet it seems to be pretty generally conceded that no general relation can be stated by formula or otherwise, which will accurately give this relation as applicable to all catchment areas.

The elements or factors determining this relation are too various and too little understood to enable the engineer to more than approximate it. The character of the surface, whether pervious or impervious, and the area of water surfaces must exert more or less influence on the amount of the run-off in percentage of rainfall, while the steepness of the slopes, the amount of forestation and the size and shape of the catchment area affect its distribution.

In comparing areas of very different sizes a considerable difference in the flow during the dry season was noted, areas of about 1 square mile yielding about 75 per cent. of the yield per square mile from larger areas.

This same general result is noted by Mr. C. C. Vermewle, C.E., in his report on the water supply and water power of New Jersey, 1894. He gives the minimum flow of seven streams, each having a catchment area of over 2000 square miles, as .182 cubic foot per second per square mile of catchment area; on twelve streams, having between 200 and 2000 square miles area, the average minimum flow was .161 cubic foot per second per square mile, and on twelve streams, having less than 200 square miles area, an average minimum flow of .094 cubic foot per second per square mile,—showing a constant diminution in the minimum flow with the reduction in catchment area.

With regard to the use of a stream for power, if the June flow be taken as the maximum flow to which it will be wise to develop a water power and the Sudbury River records be used as a basis, but about .742 cubic foot per second per square mile will be found.

I have always understood that it was the *May* flow rather than June, and Mr. Francis so testified in a case in which I was interested. In other cases I have found the actual development by mill owners to be about that given by the *May* flow. By observing the average run-off of the Sudbury River it will be found that May, December and January each give substantially the same run-off. The three months, February, March and April, give much larger flows and the remaining six, much smaller flows. It would seem reasonable, then, that a power should be developed to take as nearly as possible the flows of May, December and January, wasting the surplus in the three months of flood flow and making up with steam the deficiency during the six dry months.

Mr. T. Howard Barnes.—I am reminded, in this discussion, of the investigation of the capacity of Spot Pond as a source of water supply for Boston, made between June and November, 1845, by Messrs. John B. Jervis and Walter R. Johnson, for the city of Boston. At that date there were no run-off records of like localities such as we have now. There were records of rainfall taken at Boston and at Waltham for periods of twenty-seven and twenty years, respectively; also some evaporation observations. The run-off, therefore, had to be determined, and the direct and accurate work done by the engineers is an interesting and instructive example of obtaining results from apparently meager data.

In applying the records of the Sudbury run-off up to 1894 the safe capacity of the Spot Pond source was estimated at 1,640,000 gallons per day, based upon utilizing the storage of the pond to a depth of 15 feet—837,000,000 gallons. The estimate of Jervis and Johnson was 1,450,000 gallons per day, utilizing the storage to a depth of 5 feet—384,000,000 gallons. It should also be noted that the average rainfall over the Sudbury area, 1875-1902, is 46.38 inches, while that of the Boston records in 1845 was 39.31 inches.

The following extracts are taken from the report alluded to, and are presented here mainly because of their historic interest:

	Period.	Average daily flow, gallons.	Aggregate gallons.
1.	June 26 to July 12	2,455,300	39,285,000
2.	July 12 to July 19	7,711,848	48,521,500
3.	July 19 to July 29	417,506	4,261,901
4.	July 29 to August 7	4,674,200	42,067,800
5.	August 7 to August 17	154,448	1,533,668
6.	August 17 to August 30	2,583,500	34,195,185
7.	August 30 to September 22	894,121	19,670,668
8.	September 22 to October 2	493,640	4,766,590
9.	October 2 to November 1	937,688	28,130,635
	Total		222,432,947

Or at a mean rate, for 128 days, of 1,737,760 gallons per day equal 231,710 cubic feet, and a total bulk of 29,657,700 cubic feet.

This drainage has reduced the level of the pond about 44.5 inches, and left it so nearly exhausted that the daily flow was, on November 1st, but 329,832 gallons.

Since the first of August, when our survey of the area of the pond was made at water level, there have been drawn from the outlet 17,381,859 cubic feet, reducing the surface 23.04 inches.

The quantity of rain which has been gauged during the months of August, September and October has been 10.17 inches, and of evaporation, 15.732 inches; showing that, at this period of the year, the evaporation from the water surface exceeds the rain which fell upon it by 5.562 ÷ 10.17 = 54.69 per cent.

During the last five periods of observation in which we have been enabled to ascertain the amount of drainage derived from the watershed, it appears to have given the following proportions, viz:

In the	5th	period—	10	days	19.5	per	cent.
" "	6th	"	13	"	15.1	"	"
" "	7th	"	23	"	14.7	"	"
" "	8th	"	9	"	17.5	"	"
" "	9th	"	30	"	17.5	"	"

If each of these percentages be multiplied by the number of days in its period and the sum of the products be divided by the whole number of days, we obtain an average of 16.6 per cent., which proves that the slopes themselves, at this season of the year, evaporate or otherwise dispose of 83.4 per cent. of the water which falls upon them. These results prove the ratio between the evaporation from the surface of the pond and from that of the slopes, consisting mainly of a soil covered with vegetation, to have been—in August, September and October last—.8340 ÷ 1.5469 = 53.9 per cent.

The depth of water which the pond actually received from its watershed during the above period of eighty-five days was .709 foot, or 8.41 inches, which, added to the depth of rain given above, makes the total amount received 18.58 inches; from which, deducting the evaporation, we have 18.58 — 15.73 = 2.85 inches for the height which the pond would have risen by all the rains had no water been drawn from the outlet.

Dr. Hale has found that, at Boston, the months of August, September and October together afford, on an average of twenty-two years, 9.62 inches of rain. This year they gave, at Spot Pond, 10.17 inches, or .55 inch = 5.7 per cent. above the average, which proves that the season has not been one of unusual dryness. This is confirmed by what has been found at Long Pond (Lake Chochituate), where, in the same period, 10.4 inches of rain have been gauged, showing a difference of only .23 inch from the Spot Pond observations, but .78 inch above Dr. Hale's general average.

The evaporation gauged on Spot Pond is 6.32 inches above the general average of 9.41 inches, which, in a period of three years and with an evaporating vessel 9 inches deep, Dr. Hale obtained in Boston. The difference amounts to 67.2 per cent.

This may probably be, in great part, attributed to the different depths of the vessels employed. In our apparatus the water was always kept at a height about 2 inches only below the top of the cylinder. By being immersed in the pond, the cylinder and its contents always maintained nearly the same temperature as the latter. Hence it had at night as well as in the daytime the same evaporative power, for a given area, as the pond. More than one-third of the evaporation generally occurred during the night.

The pond being now empty, we have next to consider the means by which it will probably be filled.

Dr. Hale found, in twenty-two years, an average depth of rain falling in November, December, January and February amounting to 12.93 inches. He also found for the same four months an evaporation of 3.3 inches. If we suppose that the surface of the Spot Pond district during the ensuing four months receives the same quantity of rain and undergoes the same evaporation, the depth of $12.93 - 3.3 = 9.63$ inches $= .802$ foot would remain; and if the average area of the pond be taken at 200 acres, the direct supply from rain will be $43{,}560 \times 200 \times .802 = 6{,}987{,}024$ cubic feet.

Admitting also that the ratio of evaporation on the land to that on the water shall be the same in winter as it has been in summer and autumn (53.9 per cent.), the watershed will send into the pond, from its whole surface, a depth of $12.93 - (53.9 \times 3.3) = 11.15$ inches, or 86.2 per cent. of all the water which it receives; and this, on an area of 898 acres, will give $43{,}560 \times 898 \times .929 = 36{,}339{,}580$ cubic feet, which, with what is derived directly from the rains by the pond itself, makes 43,326,604 cubic feet supplied in 120 days. From this, deducting what has been drawn out in 120 days of our observations, which is equal to $231{,}710 \times 120 = 27{,}805{,}200$, we have left 15,521,404 cubic feet to be drawn within the following four months, leaving the pond about the height at which it stood on the 3d of July last. This affords for the average daily drainage of the two periods of 120 days in each, or 240 days in all, 180,527 cubic feet, or 1,393,950 gallons.

If we admit that the winter rains at Spot Pond will exceed those at Boston as much as did those of the autumn, viz, 5.7 per cent., the above quantity will be increased by 77,175 gallons daily, and the average daily supply will then be $1{,}471{,}125$ gallons $=$ 181,556 cubic feet. This seems the most favorable view which can be taken of the winter supply of water to the pond.

In March, April, May and June the average rain in Boston is 12.85 inches, and the evaporation, 13.26 inches; from which, it appears certain, that the pond cannot be expected to receive *directly*

in rain any accumulation or addition to its height in those four months. The only question is as to the proportion, which will be furnished indirectly by the surrounding lands. We have no direct observations which will determine this proportion. But as the months of May and June are, in temperature and moisture, not very unlike August and September, it may reasonably be inferred that the land will, in those two months, give the average evaporation of the periods which we observed, and, therefore, afford about 17 per cent. of drainage; and if we give to March and April the same proportion as the four months which precede them, viz., 86.2 per cent., the average of the four months will be 50.41 per cent. Hence a fall of 12.85 inches of rain will give $43{,}560 \times 898 \times .5395 = 21{,}103{,}600$ cubic feet of water to the pond, and affords a daily drainage for the 122 days in those months of 172,980 cubic feet, or 1,297,350 gallons.

In order to afford a daily supply of 1,471,125 gallons, the slopes must furnish over their whole area a depth of $(181{,}556 \times 122) \div (43{,}500 \times 898) = .5662$ foot, or 53 per cent. of the rain falling in these months.

The experiments and computations already given, showing the quantity of water actually derived from the watershed, do not favor the supposition that any very extraordinary proportion will be available for drainage over this district, since the highest result obtained—that for the fifth period of observation—was only 19.5 per cent.

In view of all the facts that have been ascertained and the observations that have been made, it may be assumed that a ratio of not more than six-tenths of the total fall of rain may be relied on from the district drained.

The gauge kept by Dr. Hale, at Boston, is about 8 miles from the center of the district, and that kept by Dr. Hobbs, at Waltham, is between 5 and 6 miles. The proximity is such that they may be considered in the general result as a good guide for this object. From 1818 to 1844 inclusive—twenty-seven years—the minimum fall of rain at Boston was 29.98 inches in one year. There are nine years in the series that fall below 36 inches for one year, and three years that fall below 33 inches in each year. The average for the series is 39.31 inches. At Waltham, in a series of twenty years, commencing with 1825, the minimum fall was 34.09 inches in one year, and three years in the series fell below 36 inches in each year.

In deciding on sources to supply a city with water it would not be proper to take the average of a series of years. A town will need more water in a dry season than in a wet season, and, consequently, that source only, which affords a sufficient supply at its minimum capacity, should be adopted. In a season of unusual drought no benefit or consolation for a short supply of water could be obtained, from the fact that in other years large quantities had

run to waste. If the Waltham gauge (being nearest in location, and, perhaps, most applicable) be taken, then 34 inches is the minimum; and this is strictly the proper datum for such a computation. But, as only three years out of twenty fell below 36 inches, it may be regarded as reasonably safe to assume 36 inches as the annual fall, and more especially as this will not, on the ratio of 6-10, materially exceed the lowest gauge of the commissioners in 1837 and 1838. On this basis the annual amount will be $.6 \times 3 \times 39{,}204{,}000 = 70{,}567{,}200$ cubic feet, equal to 1,446,138 gallons per day.

After a careful examination of all data that have been obtained it appears that Spot Pond may be relied upon to supply about 1,500,000 gallons per day. It may, and probably will, in some years fall a little below, but it will generally afford this quantity. The area of Spot Pond, as before stated, contains, when full, 296 acres; at a level, 5 feet below the high-water line, it contains 196 acres. Between these levels it therefore appears there are 100 acres which are covered, when the pond is full, with not exceeding 5 feet depth of water and a large portion from 1 to 3 feet in depth. This bears a proportion to the whole area of the pond of 34 to 100, or a fraction over one-third of the pond is shoal water, no part exceeding 5 feet in depth. There is, doubtless, some objection to this amount of shoal water not sufficient in depth to prevent the free growth of marsh grass and other aquatic vegetation.

Mr. Webber.—I would like to say that it was to bring out just such discussion as this that I ventured to perpetrate this paper, and because I believe there is a vast amount of very reliable data on other streams which have never been published, and which, if it were published, would be of great benefit to all of us.

For some reason or other it seems to me that on the different engineering problems that I encounter, the first difficulty I meet with is that available data do not seem to apply to the particular problems in question. I have to deal with a very small watershed and cannot find much data on small watersheds; or, with a centrifugal pump and find nobody has ever made any tests on centrifugal pumps, and so on. In the case for which I originally prepared these data I could not find anything but the records of the Sudbury, Mystic and Cochituate Rivers. Everything related to the Sudbury River. I was soon convinced that the Sudbury River was not a universal tape measure of every stream in the world, and soon found very reliable data for the Tohickon, Neshaminy and Perkiomen Rivers, which have been kept, as far as I can find out, practically ever since the introduction of the Philadelphia Waterworks. They have been very carefully kept, probably as accurately as the Sudbury River records, but were never published.

Now all these gentlemen who have spoken have some data ex-

tending over four or five years. Most of the data have never been published. That is the reason why I bring this up,—to get you to publish some of your results. There is a lot that is still tied up, owing to pending litigation, but I believe a larger proportion is not tied up and could just as well be published as not, and it is to draw out that publication that I am now making these few remarks.

I want also to corroborate what one of the other gentlemen said about the great value of plotting the rainfall and the run-off. I think records of rainfall and run-off should be plotted on the same chart, so that you can see the results at a glance, whereas you plot it on different scales. We then see on the same chart day by day and month by month the flow of the stream and the rainfall at the same time. I know in this particular case I plotted the stream in question for the run-off and rainfall daily for four years. The United States Geological Survey records are particularly valuable, because they do that very thing, besides the figures, which are harder to get a mental conception of; in almost every case there is a diagram in black and white. Picture writing appeals to a man, and he can see it much easier and better.

If we can only have published the data all these engineers have in pigeonholes, we will be far ahead, and we will not be using one tape measure to measure enormous varieties of work.

Mr. Arthur T. Safford (by letter).—I have read Mr. Webber's paper with much interest, and am glad to see this additional information to our increasing knowledge of the flow of streams.

While there is probably no question as to the accuracy of our stream measurements, I am of opinion that we can never get, in practice, the yields of streams figured upon average conditions elsewhere, unless we have storage far in excess of anything which we usually obtain. In this discussion I will confine myself to streams like the Merrimac and Concord Rivers.

This discussion was prepared very hurriedly, and I am sorry that I was not able to present more new information. It has been a part of my duty for a number of years to divide the water flowing in the Merrimac and Concord Rivers among the different mill owners; and I have been impressed with the apparent discrepancies between the average flow of the stream and the flow available for water-power purposes. Records are obtained from water powers above Lowell, the conditions of use and storage in mill ponds are studied and every effort is made to reduce waste and to make the daily use as large as possible. In spite of this a large quantity of water runs to waste during even the dry seasons,—after sudden storms,—and we never get average conditions such as the figures of

yield would seem to warrant. The extremes of flow are very great and a larger portion wasted than engineers have been in the habit of estimating. It is my purpose to give a few figures in support of the theory that unless we can store a large part of the yield and keep it in reserve we cannot count on averages.

Table XXI of Mr. Webber's paper gives for the Merrimac and Concord Rivers the following minimum and mean flows on a twenty-four-hour basis:

	Drainage area sq. miles.	Minimum flow cu. ft. per sec.	Minimum flow cu. ft. per sec. per sq. mile.	Mean cu. ft. per sec. per sq. mile.
Merrimac, at Lawrence..	4599	14.00	.310	2.19
Concord, at Lowell.....	361	59.84	.170	1.39

The minimum flow given for the Merrimac and Concord looks small, but they are not as low as the actual figures for 1900.

Mr. R. A. Hale, of Lawrence, Mass., sent me some figures of the Merrimac, at Lawrence, corrected for the Nashua, Sudbury and Lake Cochituate, in which, for the week ending September 16, 1900, the net twenty-four-hour yield of the Merrimac was but 1264 or .284 cubic foot per second per square mile. Mr. Hale's drainage area is different from Mr. Webber's, but not materially. I find that our own records at Lowell for that week show that, including the Concord and making the same corrections, the twenty-four-hour yield was 1253 cubic feet per second, without including Beaver Brook, which may have contributed just the difference between Mr. Hale's and our figures.

During this same week, the Concord River, with its 301.3 square miles of watershed, excluding the Sudbury, averaged just 16 cubic feet per second or .053 cubic foot per second per square mile. All power on the river at Lowell was shut off, and the Lowell Bleachery, which requires about 10 cubic feet per second for bleaching and other manufacturing purposes, was compelled to wait a day until the water was wasted through the gates from the mill pond at North Billerica, which had not filled up over Sunday. This is an extreme case on the Concord River, and yet it may be an ordinary occurrence, for a few weeks, on a stream where there is absolutely no storage excepting in mill ponds, which may be drawn down at will, so that the natural flow of the stream, while filling up, will be cut off.

On the Concord River, at Lowell, there are seven water wheels, drawing about 405 cubic feet per second from the Wamesit Canal, or 1.34 cubic feet per second per square mile of watershed, excluding the Sudbury. The 75.2 square miles of the Sudbury River furnishes an amount which varies from almost nothing in dry weather

FLOW OF CONCORD RIVER FROM 1888 TO 1901, INCLUSIVE, MEASURED JUST BELOW LAWRENCE STREET BRIDGE, LOWELL. THE QUANTITIES GIVEN ARE FOR MONTHS OF TWENTY-FOUR WORKING DAYS OF TEN AND ONE-HALF HOURS EACH, ARRANGED IN ORDER OF DRYNESS. FLOW COMPILED FROM RECORDS OF WAMESIT CANAL; QUANTITIES ARE IN CUBIC FEET PER SECOND.

Months in order of dryness.	1888.	1889.	1890.	1891.	1892.	1893.	1894	1895.	1896.	1897.	1898.	1899.	1900.	1901.	Average 1888 to 1901 inclusive.	Cubic feet per second per square mile.
1	164	294	228	173	164	147	84	108	127	184	253	155	69	179	163	.54
2	237	410	278	210	203	164	136	176	152	225	274	160	132	236	214	.71
3	303	571	285	226	216	175	189	193	171	256	323	169	161	256	250	.83
4	382	629	425	264	317	233	243	230	297	260	438	213	210	285	317	1.05
5	523	705	490	287	318	274	279	274	347	424	635	239	271	293	383	1.27
6	638	755	640	308	384	294	285	288	357	440	750	279	293	410	437	1.45
7	944	835	688	320	396	309	288	299	392	475	895	288	430	430	499	1.66
8	1,525	915	888	388	475	399	329	437	490	509	959	318	570	500	622	2.06
9	2,505	1,065	995	649	570	530	455	562	550	510	1,070	694	750	850	840	2.23
10	2,508	1,685	1,372	2,285	660	870	600	845	680	668	1,250	1,250	830	1,310	1,201	3.19
11	2,519	1,884	2,053	2,285	943	1,340	861	1,086	1,100	997	1,490	1,720	1,235	1,690	1,514	4.02
12	2,552	1,909	2,075	2,295	1,425	1,980	1,681	1,750	2,110	1,377	2,110	2,305	2,505	2,325	2,028	5.39

Note how much the average for each month is increased by a few wet years like 1889, 1890 and 1898.

NOTE.—Area of watershed above Lawrence Street Bridge, Lowell, Mass , is 376.5 square miles. (From Massachusetts State Board of Health Report, 1890, page 411.) Since 1879, the city of Boston has used the Sudbury River, which takes a part of the watershed of the Concord River above the Lawrence Street Bridge as a water supply. The watershed of the Sudbury River, at the lowest point of taking, is 75 2 square miles.

to about its normal yield for the few wettest months. These wheels run for 10.5 hours a day, and during dry weather there is comparatively little waste at night. The lawful quantity owned by the mills is 288 cubic feet per second, or .96 cubic foot per second per square mile from 301.3 square miles, the balance of 117 being surplus. When there is less than 288 cubic feet per second running during the working day, each mill draws its proportional part of the actual flow. As showing the actual conditions under which water can be drawn, I give the quantities drawn by the wheels during the years 1888 to 1901, made up in order of dryness, in months of twenty-four days, twelve months being equal to 288 days, or the working year, less holidays. I have added, in the last column, the corresponding yield per square mile on the basis of 301.3 square miles for the eight driest months and 376.5 square miles for the remaining four, this being approximately correct.

It is evident from the figures in this table that, even with the storage in the mill pond at North Billerica and Lowell and almost no night running, it is not possible to get the permanent quantity of 288 cubic feet per second for the four driest months, using all the years and not the average, and the six driest months during the so-called drier years. The column called average, 1888 to 1901 inclusive, however, would seem to indicate that in an average year, so-called, there would be only three months when less than 288 cubic feet per second could be depended upon, and it would be fair to infer from these same averages that it would pay to put in wheels to take at least 500 cubic feet per second to save coal in six months. If the ponds and swamps are full in the early part of the year and the rainfall comes gradually and is evenly distributed, we can depend upon average conditions, but this rarely happens; and without large storage, either in ponds on the watershed or in mill ponds, it is not possible under ordinary conditions to prevent some of the water getting by without its being used.

In order to bring out clearly the danger of using average conditions let us compare the Sudbury average yield with the measured conditions on the Concord River, of which the Sudbury contributes 75.2 square miles of its 376.5 square miles. On the basis of twenty-seven years' yield of the Sudbury River (1875-1901) the average yield in gallons per day per square mile is 1,081,000 for the year, and 441,000 for the driest six months. Arranging in order of dryness on the 10.5-hour basis and neglecting the Sunday waste, we should expect from the 301.3 square miles, outside the Sudbury for the eight driest months and for the full 376.5 square miles for the remaining four months, the following yields:

Months in order of dryness.	*Average Sudbury yield by years. 1875-1901 gallons per day.	Corresponding yield c. f. p. s. 10.5 hours.	Same reduced to 301.3 sq. miles c. f. p. s.	Average flow at Lawrence St. Bridge, Lowell, c. f. p. s.	Per cent. of monthly quantities on Sudbury basis measured at Lowell.
1	194,000	.687	207.0	163	78.7
2	238,000	.842	253.7	214	84.4
3	301,000	1.065	320.9	250	77.9
4	480,000	1.698	511.6	317	62.0
5	518,000	1.832	552.0	383	69.4
6	924,000	3.268	984.6	437	44.4
7	1,105,000	3.908	1177.5	499	42.4
8	1,163,000	4.113	1239.2	622	50.2
9	1,205,000	4.262	†1604.6	840	52.3
10	1,889,000	6.681	†2515.4	1201	47.7
11	2,075,000	7.339	†2763.1	1514	54.8
12	2,923,000	10.338	†3892.2	2028	52.1
Average for year.	1,081,000	3.823	1335.2	705.7	52.9

It is seen that on a 10.5-hour basis only 80 per cent. of the flow on the Sudbury average basis is available at Lowell for the three driest months, and that during most of the year it is not much more than 50 per cent. The Sudbury average monthly yield varies from 194,000 in July or 17.9 per cent. of the average to 2,923,000 in March, or 270.4 per cent. Individual dry months go down to — 35,000 (August, 1899), or less than nothing, and up to 4,453,000 (March, 1891), or 411.9 per cent. of the average. The weekly fluctuations are still greater and the weekly flows are controlled, to a large extent, by storms of a day. All these affect the actual flow and make it difficult to depend upon definite quantities of water.

In using the Sudbury or any other basis for water-power purposes it is necessary, I think, to know, in addition to the size of the watershed and the amount of storage, at least the average slope of the watershed, the capacity of every mill pond, the area of swamps, both on the watershed and in the bed of the stream, and the customary running at each water power, with a special study of the average height of the water there as shown by marks. Finally, with these facts known, we should apply, not the Sudbury average monthly records for a long term of years, but the actual records each month from year to year. Where large storage exists, it will be necessary to take the rainfall collected on the land surface, which increases as the ponds are drawn down, and evaporation from the corresponding water surface and actually try certain assumed yields up to the limits of the storage. This method will throw into the

*P. 240 Metropolitan Water and Sewerage Board, First Annual Report.
†376.5 sq. miles.

waste column a large part of the yield of wet years, when the storage is not sufficient to store the yield. This is ably treated in an article by Frederic P. Stearns, C.E., in the Report of the Massachusetts State Board of Health for 1890, and, in this connection, particular attention is called to the diagram opposite page 350.

I think the Sudbury basis, intelligently handled, the best one we have at present in New England; but the Sudbury average records sometimes produce results which do not exist in fact when applied to other watersheds, and give a mistaken idea of a steady flow, which is kept up during the summer and fall months by the "average rainfall collected." This year (1903) I think of as about an average year, as far as total rainfall is concerned. The rainfall for May, 1903, was .818 inches, or, with one exception, the month was the driest in seventy-five years; while June, 1903, was 9.106 inches, or the wettest for the same length of time. The careful man who began to handle his reservoirs on the basis of a dry year, this year, found a large amount of waste inevitable after the June rains.

I only use this as an illustration, but it brings out the fact that it is very much easier to look back upon records and see what could have been done than know what to count on looking ahead. There is a line between over-conservatism and risk, and good judgment will save us from either error; but we cannot fail to use every possible shred of information which can be obtained, and should not be content to accept forever the Sudbury average basis, as customarily used in court cases, as the whole truth and a panacea for all difficulties.

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THE PHYSICAL STRUCTURE OF METALS AND ALLOYS.

BY J. J. KESSLER, JR., MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Abstract of paper read before the Club, April 15, 1903.*]

THE subject which is to be considered under the title of this paper is usually treated as "The Microstructure of Metals and Alloys." This is a little misleading, as it implies that this is one of the particular kinds of physical structure which is being involved, whereas, as a matter of fact, the whole anatomy or architecture of the metal or alloy is being considered, and the microscope is concerned only in that it is an indispensable instrument of research on account of the size of most of the structural elements.

An alloy is defined by Roberts Austin as any mixture of metals, or of metals and metalloids, which, on cooling, does not separate into layers. This is a broad definition, and yet any narrower definition must exclude many substances, the most important of which is cast iron, which cannot be defined as a solid solution nor as a chemical compound, but which is a true alloy in the sense of the definition. In fact, brass and bronze are not more truly alloys than is cast iron.

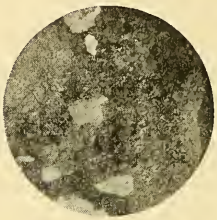
The first structural elements to be considered are those present in pure metals. It is well to call to mind here that chemically pure metals are not to be found as engineering materials. They have all, to a greater or lesser extent, associated with them impurities which were originally present in the ore or which have been acquired during the process of reduction from the ore.

*Manuscript received December 15, 1903.—Secretary, Ass'n of Eng. Socs.

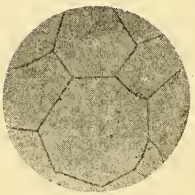
The figures shown (Fig. 1) are one and all of common character; they all indicate crystalline arrangement. Whether it be the metals lead or tin, or, at the other extreme of physical properties, antimony or bismuth, not shown, it may be seen that each metal is an aggregate of crystalline grains bounded by definite surfaces, and that no metal, however pure, may be said to be homogeneous, but that each is an aggregate of homogeneous grains or crystalline units, homogeneous in themselves, but possessing limited volume and bounded by surfaces, the forces pertaining to which are very different in character from the forces within the grains themselves.



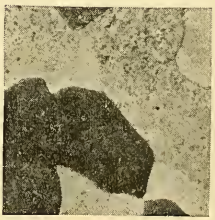
Tin.



Lead.



Iron.



Platinum.

FIG. 1. ILLUSTRATING THE CRYSTALLINE STRUCTURE OF PURE METALS.

The distinctive difference between metals, therefore, is not one of crystalline character. We cannot explain the physical difference between lead and antimony, for instance, by stating that one is crystalline and the other not. All metals are truly crystalline, and the difference between them must be found in differences in the properties of their crystalline grains and in the forces existing between the crystalline grains.

An interesting point which comes up in this connection is the effect of stress on these pure metals. When a metal is yielding to stress, and the deformation has not reached the elastic limit, no change in the structure of the metal can be recognized under the microscope. When, however, the elastic limit has been reached

and plastic yielding of the metal begins, the change is indicated in a very characteristic way.

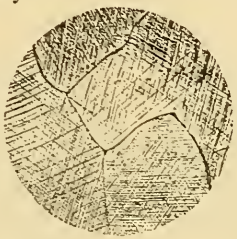


FIG. 2. PURE LEAD STRESSED UNTIL PLASTIC YIELDING HAS OCCURRED.

Fig. 2 shows an appearance quite different from that of any structure which has been yet observed. Large crystalline grains are shown as before, but on the face of each grain will be seen a number of series of parallel lines running across the entire surface of each grain, but each series ending abruptly when the boundary of the grain has been reached. These series of parallel lines are not scratches on the surface of the metal, and they begin to appear only when the elastic limit of the metal has been reached by stressing.*

This appearance of parallel lines in the structure of a metal when the yield point of the metal has been reached by stressing is common to all metals which have been thus far examined. Closer examination of the surface of the metal reveals the fact that these lines represent the connecting surfaces between parallel planes, which are at slightly different levels.

An ideal cross-section of a metal so strained would be represented as shown in Fig. 3.

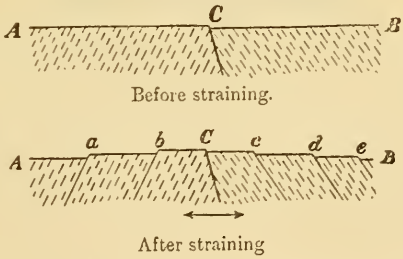


FIG. 3. IDEAL CROSS-SECTIONS OF PURE METAL BEFORE AND AFTER STRAINING.

Strain in a metal, therefore, is not a question of homogeneous shear, as in the case of a liquid, but takes place by the successive slipping, over one another, of the inter-crystalline grains. The most severely strained metal still retains its crystalline structure, the effect of the stress being to elongate the crystals in one direc-

*Ewing and Rosenhain, "Phil. Trans. Roy. Soc.," cxciii, p. 353.

tion, as in the case of rolled or hammered steel, and this is what gives the metal its fibrous qualities. The use of the word fibrous, in connection with a metal, is therefore correct, only in that it indicates either crystals elongated by stress, or impurities, present in the metal, which are elongated by stress. This is invariably the case in wrought iron, which is fibrous only when it contains elongated crystals of iron or other structural elements, or when it contains elongated portions of slag or other impurities.

Pure metals are not used in the arts, however, to the extent to which mixtures of metals are used.

Mixtures of metals, which on cooling do not separate into layers, may contain three different kinds of constituents:

(1) Homogeneous solid solutions.

(2) Distinct crystals of one substance distributed through another.

(3) Liquid solutions which on cooling have frozen into solid solutions; but which, at the instant of freezing, have separated into alternate layers of the different constituents.

These three different kinds of constituents are illustrated in the following figures. (Figs. 4, 5 and 6.)

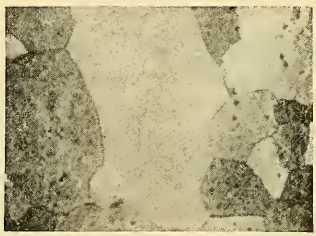


FIG. 4. SILICON IRON ALLOY (4 PER CENT. SILICON).

The first case is represented by the silicon iron alloy, which is seen to be made up simply of crystalline grains, the silicon being diffused through the mass of iron, the whole being a true solid solution of silicide of iron in solid iron, which cannot be separated from the iron by mechanical means, whose composition may vary uniformly with certain limits, and which is, therefore, a true solution.

The properties of such an alloy will be similar to those of the pure metal, and will depend on the properties of the individual grains and on the forces existing between the grains.

In the case of such an alloy it can be predicted that for any given change in the percentage of silicon present, no radical change in the properties of the alloy, over that of the pure metal, will take place; for instance, if the electrical conductivity of the metal be

represented by a certain figure, the addition of 0.01, 0.10 or even 1 per cent. of silicon will not materially affect this conductivity.

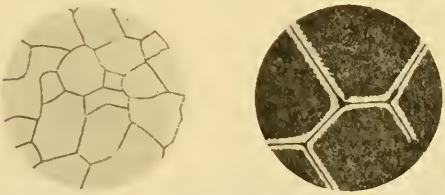
The second class of alloys may be represented by the micro-



a *b*

a, Outside of casting; *b*, inside of casting.

Pig Iron, Showing Distribution of Graphite.



a *b*

a, Pure copper; *b*, copper containing 5 per cent. bismuth.

Note.—The light and dark areas of *b* should be reversed in order to be comparable with the light and dark areas of *a*.

Fig. 5. Alloys Containing Distinct Chemical Constituents of One Substance Distributed through Another.

photographs of pig iron or of bismuth copper alloy (Fig. 5). In this case, entirely distinct constituents are seen in different parts of the metal. If the first class of alloys mentioned be compared to a solution of salt in water, the second may be represented by the case of a solution of salt and water, which has been cooled to a point where solid salt has been separated from the solution. This represents by far the most common forms of alloys. In cooling, the homogeneous molten mass separates out different constituents, which remain diffused through the still molten mother liquor, which finally freezes, forming the solid alloy. The properties of such an alloy may be entirely different from those of the pure constituents.

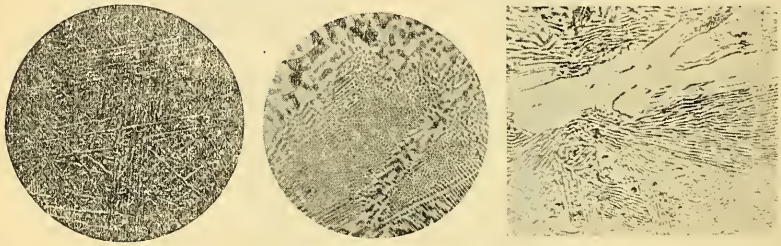
The bismuth copper alloy, shown in the micro-photograph, contains 0.5 per cent. of bismuth. This bismuth does not form a solid solution as in the case of the silicon iron alloy. In this case a small amount of bismuth unites with a large amount of copper to form a eutectic alloy (see next paragraph), and this alloy is forced out of the growing crystals of pure copper, until finally, in the solid alloy, it forms a shell of brittle bismuth copper eutectic

around each grain of copper, thus giving the characteristic brittleness and shortness to the metal. In the case of such alloys it can be predicted that, for any given change in the percentage of impurity present, a radical change in the properties of the alloy over that in the pure metal will take place.

For instance, the electrical conductivity of copper being represented by 100, the addition of 0.001 per cent. of arsenic reduces this to 99.5, or the addition of 0.010 per cent. reduces the conductivity to 95.3, the arsenic forming, with copper, an alloy similar to the bismuth copper alloy shown.

There is still another structural component of alloys, and, although seldom found as constituting the entire structure of any alloy, it forms a very important structural constituent of most alloys. This is called the eutectic alloy.

When a molten homogeneous solution of metals is allowed to cool, as has been stated, different constituents become insoluble as certain temperatures are reached. These separate out and become structural components of the finally solidified alloy.



Lead silver. Iron; phosphide of iron. Iron; carbide of iron.

NOTE.—The large white area in the right-hand photograph represents free segregated carbide of iron.

FIG. 6. CHARACTERISTIC STRUCTURES OF EUTECTIC ALLOYS.

Whether such action has or has not taken place, however, there comes a point where the remaining solution freezes as a whole. If the metals can form a solid solution, as is the case with the first class of alloys, this will be done. If the constituents are not mutually soluble to one another, a separation will take place at the instant of solidification, and the resulting alloy will be found to consist of alternate layers of the different separated constituents. A strong magnification is required to resolve this kind of structure. This alloy is always characterized by the fact of its having the lowest melting point of any of the whole series between two metals. It is, in fact, always a solidified mother liquor. The composition of the eutectic alloys of any two metals may be ascertained either by analyzing the alloy which shows the proper eutectic structure, or by studying the freezing point curves of different alloys composed

of the same metals, but of varying composition. Fig. 6 shows the eutectic alloys of several metals.

Every alloy, therefore, will consist of either one, two or all of the three different constituents named above, each combination of metals forming its own characteristic solid solutions, chemical combinations, eutectic alloys, etc., the size and arrangement of these structural units being a function of the temperature from which the alloy is cooled, the rate of cooling and the work done on the alloy, either while it is being cooled or after it has reached temperature equilibrium. It must always be remembered that simply heating a series of alloys with the same chemical composition, to the same temperature, does not necessarily imply that the alloys will be in the same structural condition; this will only be the case when the metals have been held at the required temperature long enough for complete equilibrium to take place through diffusion, etc.

Very important results have been obtained by studying the physical structure of alloys; two instances will be given where good has been accomplished in entirely different branches of metallurgy.

In the first instance it has been found that there is only one temperature from which cast steel, 0.29 per cent. carbon, may be annealed, in order to give the greatest tensile strength combined with the greatest ductility; this has been found to be the temperature which gives the smallest crystalline grains on annealing. The different results, obtained by annealing from different tempera-



Fig. 7. Illustrating the Effect of Annealing Temperature upon the Structure of Cast Steel.

tures, are shown in Fig. 7, both as affecting the sizes of the crystalline grains and as affecting ductility, as measured by the bending test and as shown by the figures of the test bars above the microphotographs, each one having been bent to the angle shown before breaking occurred.

The second field in which the microscope has proved to be of great assistance is in studying sheet electrical steel, 0.07 carbon,

with reference to the relations between its physical structure and its magnetic properties. It has been found that the lowest hysteresis is found in steel which contains the best developed crystalline



FIG. 8. SHOWING IMPROPERLY AND PROPERLY ANNEALED TRANSFORMER SHEET STEEL.

grains, and these are developed only when the steel has been subjected to a definite heat treatment.

These are only two instances of a large number of cases in which the microscope has been found to be useful in studying the physical structure of metals and alloys, a feature which is becoming recognized as being of quite as much importance to the knowledge and control of these materials as is chemical composition.

PATENT LAWS. ARE THEY ANY LONGER NECESSARY TO PROGRESS IN MECHANIC ARTS?

By George W. Dickie, Past-President Technical Society of the Pacific Coast.

[Read before the Society, October 2, 1903.*]

The subject of this short paper is one that should interest the members of this Society, although the present presentation of it must necessarily be defective, owing to the press of other matters on the time and thought of the author.

Only one week ago the Secretary of this Society requested that I should prepare a paper for this meeting, and this subject was in my mind at the time; in fact, a patent attorney was waiting to consult me in regard to evidence required to defend a suit for alleged infringement of a patent, one of a class now so numerous, where the principal novelty is in the combination of words that describe the claims.

Patents appear to have had their origin in the ancient practice of giving to favorites monopolies or special privileges in connection with the making or vending of such things as they dealt in by the reigning prince in absolute or restricted monarchies. This evil practice worked great hardship on the less-favored body of purchasers and consumers, and trade was thereby greatly restricted. The British people forced from the unwilling James I a statute declaring void all these burdensome monopolies, with the distinct exception regarding letters patent and grants of privilege as follows: "Sole working or making of any manner of manufacture within the realm to the true and first inventor of such manufacture, which others, at the time of making such manufacture, should not use, so they be not contrary to law, nor mischievous to the state by raising of the price of commodities at home, or hurt of trade or generally inconvenient." These words form the foundation upon which has been built the whole structure of the law of letters patent.

The inventions for which patents are granted are either vendible articles, such as machinery or apparatus, or processes. A mechanical principle cannot be the subject of a patent unless its application to some useful end be shown. The principal classes of patents seem to be granted on:

First. New contrivances that produce new results.

Second. New contrivances that produce old results.

*Manuscript received December 1, 1903.—Secretary, Ass'n of Eng. Socs.

Third. New combinations of old and well-known parts, whether the combination relates to the operation or to the result.

Fourth. New methods of applying a well-known device.

The spirit of the patent law is that the benefit or improvement must be manifest and of importance with regard to claims for patents touching well-known objects and processes, and great skill is sometimes displayed in so wording a specification as to bring this requirement into prominence, the object of the law being that the rewards to come to the patentee will be a just recompense to him for his labor in the wide sense that though his labor may not in itself have amounted to much, though the change in process or application be small, still, if the general scope and utility of application or process, or whatever the patent may cover, be enlarged to the benefit of the public, the inventor (though in this case only an improver) is entitled to a just reward for his discovery, and this reward his patent gives him an opportunity to secure. In the case, which often happens, of a party making some discovery not already patented, but openly used by someone else, though not to his knowledge, no patent is allowable, but should the discovery have been previously made and be kept secret, then the party who first obtains a patent is the legal inventor, irrespective of priority of invention on the part of any second party. In Great Britain a patentee may be compelled by law to grant licenses to persons to work his patent should they be able to prove that the public is being defrauded of the use of the patent.

The whole reason for the existence of patents is the monopolizing by the inventor, for a limited period, of the benefits derived from an invention, on the supposition that there will result a lasting benefit to the public after the term of the patent has expired.

A very small percentage of the patents granted meet this condition, for, to do so, they must cover real inventions. The mechanical arts have reached such a stage of development that new combinations of mechanical devices, in the sense of invention, is hardly possible, and, in my opinion, a patent should be issued only where some new contrivance has been invented to produce a new result. I would not have any real inventor go unrewarded, but, in order to recompense the few inventors who have done work worthy of recognition by their fellow-men, it should not be necessary for the public generally, and the mechanical arts in particular, to carry the huge load of patent-protected devices of all sorts described in patent specifications, which, owing to cleverly worded claims, prevent a free application of the proper device to accomplish the end in view.

I have reached my present position on the patent question through experience in my daily task of continually seeking the best mechanical means to accomplish the end in view. In order to illustrate the kind of patent that stands in the way of progress, seeking to exact royalty on claims that should never have been allowed, I may cite a case where the holder of a patent is at present claiming damages from the company with which I am connected for alleged infringement of the claims on which he has been allowed a patent:

In 1898 the United States Navy Department issued specifications for three battleships. On page 37 of that specification there is the following requirement: "Lifting gear to be provided for all armored hatch covers which can be worked by hand power from above and from below. Such shutters and doors of armor as may be directed are to be fitted to be opened and closed by electric power, the electric power appliances to be worked without disconnecting the hand gear." And on page 49 there is the following requirement: "The principal sliding water-tight doors below the protective deck, as directed, to be operated on an approved system by power, each such door to be capable of being operated by hand or power from either side, and all to be capable of being closed simultaneously from a distance by power from two stations located as directed. The distance control must not incapacitate each door from operation on either side at the door by power."

A company had been making doors for such use under patents. These were at first hydraulic doors, but after some experience with them new patents were obtained for doors operated by air, and now this company has bought or otherwise secured patents for doors operated electrically. The claims under these patents are all very broad and cover the combination of a door, the bulkhead to which the door is secured and the mechanism for operating the door. Now, bulkheads are not new, doors secured to bulkheads are not new and mechanism to operate doors attached to bulkheads is not new. But to come back to our case: In October, 1898, the contract for one of these three battleships from whose specification I have quoted was awarded to the company with which I am connected, and, after the more important matters connected with the beginning of such a contract were attended to, I began to consider how I would meet the requirements of the specification as to doors and hatches to be operated by power.

Some time in December, 1898 (exact date unknown, for we never consider that what we do at any time may be required as evidence in a patent case), I talked this thing over with our

electrician and decided to operate these doors and hatches by electric motor, using the ordinary vertical sliding door frame and screw, simply taking the doors we had been making for years, applying a special motor to operate the screw and using the control devices that we had used for other purposes, it never occurring to us that any invention was required to meet the case.

We could not start the plans for these doors for some time, owing to press of other work. I find, however, that on February 13, 1899, I wrote the president of our company, who had sent me a proposed plan from the other company offering their hydraulic doors for use in this battleship, as follows: "The number of vertical sliding doors for the ship has not yet been determined, nor what number of them should be operated by any power system at a distance. Our intention is to devise an arrangement for operating them by electric power, and we will take it up as soon as we can possibly get at it. The prices given for these doors are altogether too great to make it advisable to think of using them." About this time I think that we must have begun to make plans for these doors, as the contemplated plan was signed and dated May, 1899. A sample door was made, and a sample portion of bulkhead to which the door was attached, the bulkhead being in the form of a tank to test the water-tightness of the door. This was set up in the shipyard some time about July, and the door was thoroughly tested and found to operate very satisfactorily. Here, again, I cannot fix dates, for it never occurred to me that I was inventing anything and that evidence would be needed to establish who the inventor was, there being nothing new about any of the devices used. When the door was found satisfactory, the plans were submitted in the usual manner and approved, and the work was started.

In November, 1899, I was in New York, attending the meetings of the Society of Naval Architects and Marine Engineers, and there learned that the naval constructor at the New York Navy Yard had been getting up an electrically-operated door to meet the requirements of the specifications from which I have quoted, and had a sample one set up at the yard. He invited me over to the yard to see his door and note in what way it differed from the one I had designed, so I went to see it and found that it also consisted of a combination of well-known devices, although differing from mine. He used a rack on the back of the door instead of a screw, the pinion gearing with the rack being carried on a shaft, which also carried a worm wheel, in which the worm on the motor shaft geared. This was not so simple as the motor

direct on the screw, as I had it, and has not proved so effective. We talked freely about the difference in the doors, each trying to show the other where his door had the advantage, but neither said anything about being an inventor.

About a month after this the naval constructor made application for a patent on his door, with broad claims covering the combination of a bulkhead, a sliding door and motor, with controlling devices for operating the door. This patent was granted in 1900, sold or assigned to the before-mentioned company, who have started suit against the company with which I am connected for a large amount of damages and injunction against using the door I got out to meet the requirements of a Government specification. It may be said that such a suit will not be successful, but it will cost the company several thousand dollars for its defense.

I have stated this case at length because it is the best illustration I have at present of the kind of patent business that should be stopped. In this case (and it is representative of ninety-nine cases out of every hundred) there is no invention required. The door is the same as has been used for many years. The wedges that force it on the face when it reaches the proper position are the same as have always been used for that purpose. The screw that works the door, either vertical or horizontal, is the same as has always been used. When operated by hand it could be operated either at the door or at a distance. By and by a specification requires it operated by power, and I decide to do it electrically. For this purpose I use a motor such as we had used for telemeter purposes, gear this motor properly to the screw that operates the door, use well-known devices for controlling the movements of the motor, both at the door and at a distance, and in doing this it never occurred to me that any invention was required to combine these various well-known devices. At the same time a Government officer, knowing what this specification required, also took a door, such as had been used for many years, with the wedges to force it on the face when it reached the proper position, discarded the screw that had so long been used to work it by hand, fitted a rack on the door, a pinion to work in the rack and a shaft with a worm wheel on the shaft—a motor with a worm on its shaft to work in the wheel and with well-known controlling devices at the door and at a distance. After his door was finished it occurred to him that he had invented something in connection with it, and he applied for a patent with claims covering the whole combination. The patent was granted and then sold or assigned to the company that brings suit to recover damages from others who had the door

in operation several months before any patent was applied for. Had I thought anything was being invented when designing this door, I could have applied for a patent several months before the other. Now an expensive defense must be made against the claim of the party holding this patent, although, if invention were necessary to the securing of a patent, this party could not have obtained one.

I do not wish to be understood as opposed to all patents. I believe in rewarding everyone who, by invention or skill, succeeds in making new combinations of well-known devices to accomplish results whereby the public will be ultimately benefited, and I would have such rewards liberal and sure; but patent claims cleverly worded to cover combinations of well-known devices—to accomplish well-known results obtained for business purposes—that are to prevent others from using the same combinations or mechanical equivalents I would abolish, and thereby stop 90 per cent. of the patent business, with decided advantage to the real inventor, who at present is lost amid the multitude of imitation inventors and patent sharps.

What I propose would hardly be received kindly by the general public. The general public's heart is quite soft in regard to such things. It is generally believed that the inventor is a mechanical genius who needs protection, pursured as he is by a host of designing capitalists trying to deprive him of the fruit of his labor, his only protection being the patent laws. The individual who touches the public heart as a struggling mechanical genius, who will be crushed if not protected, does exist, but he is very rare, and one of the reasons why he has no chance is because of the multitude of pretenders. Remove the vast accumulations of so-called inventions upon which patents have been granted which have neither merit nor novelty, then there would be some chance for the public to find the real inventor and reward him in such a manner as would ease the public conscience. This might be done by either granting a patent where a real invention has been made (such a patent would have a value which under the present conditions is hardly possible) or the claims of an inventor could go before a commission composed of business men, each of high standing in his line of work, and so constructed as to cover the whole field of applied mechanics and processes of manufacture, who would administer to the inventor from the public purse a direct reward, which would be in proportion to the merit of the invention. There would, no doubt, be many objections to such a scheme because of the multitude of patents issued on what are not in any sense inventions, the holders of which

reaping where they never did any sowing. All that multitude of patentees, including those whose business it is to prepare the way for inventors to obtain patents and protect them in the sole use of them, and the still greater multitude who expect to be patentees, although in no sense inventors, will have many objections to any method such as I propose, by which the real inventor might be able to bring himself into the light and receive a just reward for what he has done. It is because of this strong opposition that I have brought this subject before the Technical Society, in the hope that it may be fully discussed. Some of the most prominent men in the application of the mechanical arts to our industries are beginning to look for some way whereby this huge incubus can be lifted from the free use of mechanical combinations that have been free until some clever patent expert, whose client wanted a patent, was able to so word a claim as to tie up the use of some well-known device. It may be claimed that the examiners at the Patent Office are competent to protect the public from the evils I have pointed out, but these men know nothing of what is going on in the great industrial establishments, where the real inventions, that result in progress, are being made every hour of the day with no thought of protection from patents. The Patent Office examiner is concerned only to find whether someone has not patented the same thing or combination of things before. The real inventor has a harder time to satisfy the Patent Office expert than the combination man. The inventor must have something that is entirely new, something which the Patent Office, in all its years of collecting, has never had before, but the combination man has only to make a new arrangement of words to describe his claim. The courts also are supposed to protect the public against unjust patents, but, besides the expense involved in defending an action for infringement, there is the difficulty of procuring evidence of use. If one has to go back several years for it, it is often difficult to obtain. Drawings, made without any thought of their being required for anything except to get out the work by, are often found without date. Instructions are often given to carry out work in a certain way without any evidence being preserved of the when and why of such instructions. Those who are engaged every day in making all sorts of mechanical combinations to fulfill requirements in the specifications that describe the work under the various contracts they are endeavoring to execute have no visions of fortune through patents coming to them. They do not consider themselves inventors, and they never think of evidence in regard to their daily

work. Yet these are the men who have advanced the mechanical arts to the place they occupy in the industrial world of to-day.

I trust that this imperfect presentation of this most important question will be carefully considered and discussed by the members of the Technical Society. We are all more or less interested, either directly or indirectly, in patents. My side of this question is not the popular side. I have long felt it to be the right side. I have brought it forward at this time not on any sudden impulse. It has been a growing conviction with me for the past twenty years that a change is needed in the patent laws, and that this need is growing more urgent every day.

PATENT LAW ADMINISTRATION.

By John Richards, Past-President Technical Society of the Pacific Coast.

[Read before the Society, November 6, 1903.*]

The present paper has been produced a piece at a time, as opportunity permitted, and it will lack the order and sequence desirable in such contributions. For one thing it will discuss but briefly the effect of patent grants on industrial development, which should have been a main theme. The reason is that this subject was reserved as a separate part, and is shut out for want of space and time; also, because it is not demonstrable by facts and can safely be left to inference.

I have read with interest and approval the remarks on patents for inventions presented at the last stated meeting of the Society by my friend, Mr. Dickie, and, as this paper was brief, I venture to submit something further in respect to the patent system of this country, with some remarks upon the same subject as represented in other countries.

At the beginning I am willing to concede the abuses that arise out of procedure, meaning by this term the conduct or administration of the patent laws, but I must contend, on grounds of natural right as well as of expediency, that the policy of such grants is well-established by the fact that all countries where there are industrial interests to promote have patent laws, Holland excepted.

In Switzerland, where we may look for the most enlightened laws and policy in such things, the patent laws were for a time abrogated, and again restored on nearly their former basis, so that the equity and expediency of such grants can scarcely be called in question.

There is also the further fact that British laws, from which the system originated 280 years ago, have changed but little in all that time. I have brought with me this evening copies of British patents more than 200 years old,—in one or two cases more than 250 years old,—from which it may be seen that no great change has been made in all that time.

From England the system of patent grants for inventions spread widely over the world, our own dating back something more than a century, the present indices reaching to 1790. It is an interesting study to examine the development of this patent

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system and the impediments which had to be overcome because of the paucity of technical knowledge and skill required to administer such a bureau in a new country, where science and the technical arts had a narrow foothold until comparatively recent times.

It will be remembered, no doubt, by many here this evening that down to 1870, or later than that, each inventor had to supply a model of his invention, in order to enable the officers of the Patent Office to understand its nature and its manner of operation. Not only this, but the drawings supplied had to conform to the model, and, as models were naturally crude, the result of this can be imagined. No other country, that I am aware of, except Canada, adopted such a feature, but in Canada the drawing and model were not required to correspond, so the model happily dropped out, though a little later than in this country.

This method, which called out a good deal of ridicule in other countries, has left us a legacy of useless lumber, which still occupies a good deal of room in the cramped space where the Patent Office work is carried on. Some of these models have interest historically and some of them are well made, but destruction would be a proper treatment for three-fourths of the whole.

The operation of the patent laws went on with measurable uniformity in different countries until within a few years past, when the German Bureau initiated a reform that will no doubt extend to other countries where technical knowledge is sufficiently advanced to permit such a system. This change is fundamental in its nature, but not very easy to explain in a popular way. It would, no doubt, satisfy my friend, Mr. Dickie, but it is not, however, likely to prevail here during his time or mine. It consists in a measure of novelty and utility on grounds almost the reverse of present practice in this country. Our laws permit or grant patents on the means or agents of production only; that is, on contrivances or discoveries that produce results, and particularly bar patents on principles or on modes of operating. This, it will be seen, opens the door for endless patents on nearly the same thing, with slight differences that often turn upon mere phrases of speech.

The German Government grants patents on results, or, in their terms, on "new technical results," paying but little attention to means or implements. Claims to express compendiously the subject-matter of an invention are limited to one that must involve what is called a "unitary concept." Other claims may be added, not more than three, explanatory of the first. This plainly involves a complete change of system. The controversy concerning Mr.

Dickie's bulkhead doors could never have arisen under a law and practice of this kind.

It would be an enormous innovation in this country for our astute patent agents, who can write twenty permutation claims on a nutcracker, but it is an advance to a higher plane, is logical and must commend itself to all who will analyze the true spirit and intent of patent grants for inventions. This juggling system of "permutation claims" is a distinguishing feature of modern practice in this country. It is a device that had its origin with patent agents, and because the claims in American patents were construed separately and independently. It is the reverse in England, where a patent falls with each and any of its claims; and in France, where, until very recently, a patent required no claim at all separate from the body of the specification. This latter system permitted full discretion to the courts, and this discretion, I am glad to say, has been seldom abused.

Our own courts have to deal with words and cunningly devised phrases instead of the essence, nature and scope of an invention, and, having a dread of subjects they cannot possibly understand beyond a construction of terms, the justices are apt to follow each other in their decisions on any issue. This was the case in the celebrated Woodworth patent suits early in the last century, when there were twenty-two suits at law over the invention of a "combination of feeding rollers and rotary cutters," which invention you will find in the British patent of Bentham of 1793, among the copies present this evening.

I am recounting these features of practice for two reasons: First, in order to show how difficult it is to administer the patent laws, and especially procedure in the Patent Office; and, secondly, to invite comment on some means of attaining a more intelligent and just procedure in that department.

The statute law relating to patents is printed on 32 small pages containing about 15,000 words, and is, in itself, quite simple and understandable; but this law is supplemented by endless decisions that attempt to fit the application of these laws to the circumstances of industrial inventions, and it is doubtful whether any human power could codify this maze and bring it into a harmonious relation with the arts.

The "Rules of Procedure," 214 in number, emanating from the Commissioners of Patents and their advisers, is a more extensive matter than the law, occupying 100 printed pages and about 47,000 words, much of which should be embraced in the statutes. These rules are intended for the instruction and guidance of the exam-

iners and patent attorneys. They are often changed and extended to meet the constantly recurring problems that arise in an attempt to fit laws and administrative rules to science and the arts, which is, in the nature of things, impossible.

This impediment is fundamental and perhaps insuperable. The two things cannot be assimilated. Science and the arts are computable and exact. They deal with definite dimensions, fixed natural laws and skill, the latter meaning a personal recognition and acquaintance with these qualities, or quantities, and with the modes of their operation. Statute law is inexact, uncertain and mutable. It does not deal with dimensions or exact quantities of any kind; not even, except in an indirect way, with modes of operation. One may read through a law treatise, even on patent law, and not find in it a single thing that has a base in anything exact and proved, except, perhaps, a chemical formula. Men skilled in statute laws are seldom or never qualified to deal with the technicalities of the industrial arts, and, consequently, not capable of determining the nature, scope and relations of inventions.

Conversely, those skilled in the arts and accustomed to the exact results of science are apt to look with indifference and suspicion on the unstable laws and procedure relating to patents for inventions. The basis for this work must be facts, measurable and computable; things must co-relate, must have constant sequence and must be uniform. Law and the practice of law are none of these things, but are arbitrary, uncertain and frequently illogical.

It is not easy to make the difficulties of administration clear, but your own consideration of them will, no doubt, confirm the fact that neither this nor any other Government has resources from which to draw officers to administer a patent bureau according to the spirit and intent of the laws.

Germany, which established excellent and numerous technical schools about 50 years ago, is at this time nearer than other countries to providing a corps of officers competent to pass upon and award patents for inventions. These technical schools had no marked influence over the industries of the country for 30 years or more, but now we can see their effect in many ways. In Saxony alone there are 287 industrial schools. The chemical industry will show the influence of this kind of training.

In Germany there are more than 6000 establishments making chemical products, employing 135,000 workmen. One of these, at Manheim, which I have seen, employs 6000 workmen and 148 chemists, besides the clerical force. With few natural resources

for chemical products, Germany managed to send into this country last year $14,000,000 worth of such manufactures.

Under such circumstances, where there are thousands of qualified men available to conduct this department in a patent bureau, we should naturally look for good practice; and, as I have before pointed out, their system is likely to produce imitation in other countries.

It is likely that an impediment to this system will be found in its paternal nature. The law provides that each patent granted must include an "invention," and, as no law can define what an invention is, this point is left to the decision of the officers of the bureau at Berlin, qualified by the provision before named, that an invention must produce a new "technical result" and consist of a "unitary concept."

This is vague, but is as far as law can go. It reaches the point where personal knowledge of the arts must begin; in other words it is the point where technical knowledge and impartial administration must take up the work and brings us to what we call "procedure," in which a German officer is supposed to ignore nationality, forego his prejudices and act impartially. Time will show whether this be possible.

In this country the enormous activity of industrial production furnishes a field that absorbs the technically trained people, and few are available for the Patent Bureau. On the contrary the legal profession is overflowing and aggressive, and, as patents for inventions are commonly understood as a matter of law instead of technical discrimination, the result is what Mr. Dickie complains of in his paper.

An examiner-in-chief, of which there are three who sit as a board of appeal in contested cases, receives the sum of $3000 a year; a principal examiner, the head of a division, gets $2500; a first assistant examiner, $1800 a year, and from this the salaries run down to $1200 a year for fourth assistant examiners.

There are 200 officers who come under the head of examiners, and in all between 700 and 800 people employed by the Bureau, a large proportion of whom seem to come from the New England States.

It is an amazing example of routine work, done by rule and apparently without personal discretion—by rules that have grown out of the conduct of the office and the circumstances of procedure.

Changes—even the slightest—are ventured upon with timidity, and, while it is easy to discern much that seems illogical and wrong, it would be hard to see how any successful change can be made

without starting at the very beginning with a new law relating to patents for inventions.

The functions of examination and rejection are the salient features of our patent system, and, consequently, must form an important part of this paper. Examination, so far as advisory, is a proper and useful function of the Bureau and its officers, and is more complete in this than in any other country at this time, so far as the records of the Patent Bureau furnish a basis; but rejection is quite another matter.

It is this paternal and arbitrary procedure exercised by the officers of the Bureau that has led to a common belief that a patent is an "act of grace" and a favor or privilege conveyed and confirmed by the action of the Government.

This idea is a logical sequence, because rejection is naturally a corollary of "confirmation," and no one can well conceive of a power to destroy without a corresponding power to sustain.

The rejection of a patent is in its nature a paternal act, wherein the Government assumes a function that properly belongs to the citizen. The applicant is not permitted to use his own judgment as to what he can maintain and defend, but is taken care of, so to speak, and instructed as to what he shall have the privilege of maintaining, by the judgment of an officer who can destroy but cannot confirm. This is paternalism and establishes a common conclusion in the minds of applicants, and, indeed, in the minds of all except those who have studied the patent laws, that they are to receive with a patent a confirmed right.

Patent agents all over the country will bear evidence to the existence of this opinion among their clients, who look upon the examiners as holding in their power a favor to be bestowed or withheld. "Get all you can" are the instructions, but these same people are generally very cautious respecting their claims in other countries, where personal responsibility is the same. It may at first thought seem a strange proposition that the rejection of patents should increase the number and lower the character of applications, but I am satisfied that it does so.

Thousands of applications are made that would never appear if the applicant and his attorney were made responsible, as in England, for the scope and novelty of inventions as presented to the Bureau. I judge of this matter by the fact that patents are more respected there than here, and are as seldom repeated and more often sustained in the law courts.

I am aware that this has been disputed, but I speak from an

experience of thirty years or more in both countries, dealing with articles of manufacture, many of them protected by patents.

What the result may be in Germany and in some other countries that are extending their patent bureaus to include a corps of examiners one cannot conjecture at this time, but it is highly probable that this paternal system will not in the end have the effect desired, unless such desire is to destroy property in invention, which to an increasing number of people at this day would be a welcome consummation.

Returning to our own Patent Bureau, the paternal idea which manifests itself by rejection leads to certain administrative anomalies.

For example a primary examiner, instead of acting in what may be called a professional capacity, performs routine duties in which his individuality is usually eliminated. He does not even sign his decisions and has no power to amend them; no matter how mistaken they may be they must go permanently into the record.

But, strangest of all, he exercises a "triple function," so to speak, being a whole tribunal in himself, acting as witness, counsel and judge. He prepares the evidence, presents it as attorney for the Government as against the client and then passes judicially upon his own findings by deciding whether the applicant shall or shall not have the privilege of defending his claims in the law courts. These duties, instead of being professional and advisory, are arbitrary; they consequently fail to command the confidence of inventors and put the Bureau in a false position before the country.

At present, in some European countries, where examinations are made in respect to novelty as well as to form, it is common to have a communication from the Bureau pointing out that an invention is in part or wholly anticipated, or that the specification is too broad in its statements and claims, but there is no "rejection," except in Germany, nor is there authority for that. The applicant can proceed at his peril after such notice, on his own responsibility, but, of course, will always amend his specification to avoid references which he or his attorney had failed to consider.

I am inclined to think that our patent system, or the manner of its administration, has, in some cases, exercised a restraining influence on certain arts.

As a case in illustration: Among those interested in the subject it is a matter of common knowledge that inventions pertaining to hydraulics have for many years past met with scant encouragement in the American Patent Office, and that, as an example, our

water-wheel practice, a very extensive interest, is in certain types distinctly behind that of France, England, Germany and Hungary, a fact that appeared when the Niagara Commission met at London in 1890 to consider water wheels for the Niagara Falls scheme. American makers presented no plans that the Commission considered, or even mentioned, in their report, except one tender from San Francisco for tangential wheels, which I had the honor to prepare.

Pressure turbine practice in this country, except as to one type, the centripetal or central-discharge one, came from France, and the best examples in use here were made under the patents of Fourneyron and Jonval, while the Girard type, that was best suited for use at Niagara and for high heads, was not until 1893 made in this country at all, and was then so badly made as to fail, so that no impulsive-acting wheels of any kind were made, down to the evolution of the tangential type on this coast.

How a country where so much water power is employed under all kinds of heads and conditions could go on until a few years ago without any manufacture of the type of water wheels known as the Girard class of unfilled or partial turbines, one of the most common in Europe, will appear if we examine the history of some early inventions here.

In February, 1853, fifty years ago, Mr. Jearum Atkins, of Illinois, I think, filed in the Patent Office at Washington an application for an improvement in water wheels of the unfilled or impulse type, and in his specification set forth, in the form of a well-written treatise, the principles on which his wheels operated.

This application was promptly "rejected." No unfilled turbine had been seen before, and Mr. Atkins, being a poor man without resources, and an invalid besides, was not able to prosecute his case by appeal or otherwise, and, as the patent could not issue because of "rejection," he was unable to work his invention, except to make one very successful wheel; so the invention was strangled, so to speak, by rejection.

About 1860, seven years later, Messrs. Escher, Wyss & Co., of Zurich, Switzerland, began making water wheels of the same type, and the practice rapidly extended all over Europe, especially in France and Switzerland, and, as I have remarked, came back to this country in 1890 through the plans of the water wheels at Niagara, which were made from drawings furnished by Messrs. Faesch & Picard, of Geneva, Switzerland, who, with four or more other European firms, tendered full designs for the construction of these wheels.

In 1875 Mr. Atkins's invention was somehow resuscitated at the Patent Office in this country and a patent was issued to him, but too late to do him any good or to aid in founding the manufacture here. Mr. Atkins, when I last heard from him, was living at an advanced age in the Mechanics' Home in Philadelphia.

He was an original inventor, perhaps the first to discover and explain what are called impulse or open-turbine wheels, in which the discharge vents are larger than the inlet ways, and was the first, in this country at least, to lay down in a clear manner the principles involved in this kind of water wheels, which include the tangential type extensively made and used on this coast.

Suppose the patent of Mr. Atkins had been issued in 1853, even with all the objections that were urged against it in the Patent Office, no one will doubt that the inventor's representations and his better understanding of the subject would, in either a business way or even in suits at law to defend his invention, have been quite sufficient to work and sustain his patent; and if this had been done, this country would have reaped a great reward from the invention.

It is not contended that the examiner should have known that a turbine water wheel would operate when not filled and when the discharge passages had double the area of the inlet ways. A recorded opinion to that effect would by no means have destroyed Atkins's patent if it had been issued at his request, but "rejection" took away his power of utilizing the invention and destroyed it, whereas it is quite sure the courts would have sustained his claims, notwithstanding the action of the Patent Office.

I could go on and show that in centrifugal pumps, gas engines and other important manufactures procedure in the Patent Office has hindered progress. Just at this time I have failed to have a distinction made between impulsive-acting and pressure fluid machines operating by steam. Both types seem to be in one class, although their manner of operating is essentially different.

It is like the old problem of 1853, or, rather, is the same problem over again, and the result is that there is not a manufacture of impulsive-acting steam engines in this country that is not either an imitation of European practice or paying tribute to foreign inventors. The first successful engines of this type, of which I have any knowledge, were made about eighty years ago by William Avery, of Syracuse, N. Y., an uncle of Prof. John E. Sweet, who made fifty or more, and, as I have just remarked, there is not at this time a separate division in which these engines could be classed in the Patent Office.

In 1895 a distinct invention in ignition apparatus for gas engines was made by Mr. Geo. E. Hoyt, of San Francisco, in which the "time function" was regulated by resistance and distance of flow of the gases into a tube, having a small bore about one-thirtieth of an inch in diameter. This invention was presented and persistently prosecuted before the Patent Office for two years. The inventor sent to the office tubes 5 inches and others 30 inches long, with affidavits to show that both had been on the same engines under the same conditions, and that it was the contracted bore, resistance and consequent velocity of flow into the tubes that determined the time point of ignition.

The claims were rejected by the primary examiner on irrelevant references, and by the examiners-in-chief, and was abandoned because the parties in interest concluded, and yet believe, that the invention was opposed on technicalities and not considered on its merits as an invention. This was the last application for letters patent filed in this country by that company. They are still prominent makers of gas engines here.

One examiner will be said to act carefully and impartially; in another division, it will be said, nothing escapes rejection, and attorneys dread to send in cases. Any experienced solicitor of patents will confirm this statement. Its significance lies in the fact that the present rules do not provide impartial administration.

There is no intention to disparage or underrate the eminent attainments of a large number of officers in the Bureau, but even these are bound by a routine of rules and precedents that prevent personal and responsible action in technical matters. They are bound to consider terms and forms of speech that are purposely made entangling and obscure, and not the essential facts.

In chemistry and other of the sciences that can be called exact, the procedure in the Patent Office is all that could be desired, and it is a wonder that the same or corresponding ability cannot be commanded for what we may call the dynamic and mechanical divisions. Imagine, for example, in chemistry or electricity, the want of distinction between two qualities or forces so unlike as the pressure and impulsive action of fluids.

I do not feel qualified to suggest a remedy for the features of our patent system that have been criticised, but strongly suspect that the German laws and procedure are a distinct advance in some of the objects to be attained by a patent system. I believe that the number of patents granted in this country, about half a million a year, could be well reduced to one-third as many by the requirement that each patent should relate to a new "technical result,"

and not a means alone; that patent attorneys should not be admitted to registry or to practice in office procedure unless competent and qualified, as in other professions; that the actions of the primary examiners, which are now a part of the permanent record, should, with amendments, be printed with each patent; that the power of final rejection be taken away from the primary examiners and exercised by different officers, capable of judging impartially of new technical results; that the appeal tribunals of the Bureau, now wholly inadequate, should have more time and facilities for their actions; that the salaries of the chief and first-class examiners should be doubled, so as to command higher technical qualifications for this intricate and responsible work.

There are now, I believe, about seventy legislative bills before Congress relating to the Patent Office, most of them bad; but, this being a national matter, and as we have no national representatives in Congress, such legislation receives but little attention, and, with a surplus of between four and five millions of dollars lying idle in the United States Treasury, the Patent Office is crowded for room and without facilities for conducting its enormous business, constantly increasing in volume, and certainly without a corresponding useful effect on our industries.

In 1902 applications for patents in this country numbered 49,499. Of these, 27,776 were passed, the rejected and abandoned cases being 21,714. Expired patents, granted in 1885, were 21,714, which shows an increase of more than 6000 since that time. Where this is to end no one can foresee, unless some means is discovered of confining patent grants to those who produce some new practical result and whose claims can be understood by the public.

Of patent agents there are now about 3000 registered in this country, which number, divided into applications filed, gives less than eighteen cases a year for each and for patents granted nine for each attorney, which should return the munificent sum of about $200 a year for fees.

The criticisms of Mr. Dickie are well taken, but it is not the laws that are at fault so much as the administration of them.

Finally, I will venture the opinion that we are at the beginning, or a little beyond the beginning, of a war upon property in inventions, a war which will no doubt be conducted with extreme subtlety by those who own large amounts of capital and who recognize that as the only interest that should absorb the earnings of industrial production.

As signs in this direction may be mentioned the erratic administration mentioned in this and in Mr. Dickie's paper; the want

of room for the Patent Bureau and especially the paucity of legislation and attention given to this subject; the character of the bills now before Congress, and the growing opinion, if not belief, among large owners, that small or individual enterprises such as are founded on patents should not exist.

The first movement in this war against invention will be to render patent grants unpopular, and finally obnoxious, by representing them as monopolies and by encouraging bad administration.

The honest administration of the Bureau and of the appellate and circuit courts is seldom called in question, although dealing with vast and intricate interests, and this circumstance has, no doubt, warded off attacks that would otherwise have been made upon the system.

This claim of honesty and pure administration, however great the errors made, is one of especial weight when so much of an opposite nature characterizes our time, and we may be excused for some congratulation over the fact that engineers and mechanics deal with truth and ascertain facts, and that even the romancers never choose their villainous characters from these callings.

OBITUARY.

Alphonse Fteley.

Member of the Boston Society of Civil Engineers.

[Read before the Society, December 16, 1903.]

Alphonse Fteley was born in Paris, France, April 10, 1837, and died June 11, 1903. He was educated in the Government schools and obtained an academic degree from the University of France. Subsequently he attended the École Polytechnique in Paris, was graduated therefrom in 1859 and at once began his professional career.

For six years he was engaged on varied engineering work in France, after which he came to the United States in 1865. His first work in this country was as a mechanical draughtsman on the construction of machinery for river steamboats, and at the same time he was engaged in the study of the English language. The next year he entered the office of the late Mr. William E. Worthen, where, as general assistant, he was employed on civil, hydraulic and mechanical engineering until 1870. He then opened an office in New York City for general engineering practice, especially in the line of hydraulic engineering.

While in general practice, he was at times professionally associated with Messrs. William E. Worthen, James P. Kirkwood and other prominent engineers. At one time, while assisting Mr. Worthen in experiments upon the efficiency of the pumping engines of the Brooklyn Waterworks, at Ridgewood, he contracted, by overexertion, a peculiar heart trouble, which weakened his physical powers in some respects and made more difficult his life work.

In May, 1873, Mr. Fteley was called from New York to Boston to take charge, under Mr. Joseph P. Davis, City Engineer, of the construction of the Sudbury River Waterworks. The construction of these works, which was somewhat delayed by many additional investigations, required by the city government of Boston, continued until 1880. The works consisted of an aqueduct 16 miles long, including in its length tunnels, arch bridges and siphons, storage reservoirs and other works pertaining to a water supply. His success in the construction and in the design of many important features of these works gave evidence of his eminent skill as an engineer.

It was during his connection with this work that the accurate gaugings of the flow of the Sudbury River, which have since become

classic, were inaugurated, and during this time also, in connection with his assistant, Mr. Frederic P. Stearns, he carried out important hydraulic experiments upon the flow of water over weirs of various forms, upon the flow through aqueducts and upon the accuracy of current meters. The results of these experiments were contained in a paper presented to the American Society of Civil Engineers in 1882, for which the Norman medal for that year was awarded.

In April, 1880, when the Sudbury Works were substantially completed, Mr. Fteley accepted a position as Chief Assistant City Engineer of Boston, the position having become vacant by the resignation of Mr. Davis as City Engineer, and the promotion of his chief assistant, Mr. Henry M. Wightman, to his place. While occupying this position, he was engaged upon the design of various works for the city, including important parts of the main drainage, water supply and park systems.

On January 23, 1884, the Aqueduct Commissioners of New York, who were about to begin the construction of new works for increasing the water supply of that city from the Croton River, appointed Mr. Fteley to the position of Principal Assistant and Executive Engineer, under Mr. Benjamin S. Church, Chief Engineer. This title was subsequently changed to that of Deputy Chief Engineer. On July 21, 1886, Mr. Fteley was appointed as Consulting Engineer.

That Mr. Fteley's previous experience was of especial value is indicated by the report of Mr. Church, dated January 1, 1887. He says, "As Principal Assistant and Deputy Chief Engineer, Mr. Fteley has assisted me throughout the preparation and organization of the work. I had especially put under his able direction the professional study connected with the design of the aqueduct and of Quaker Bridge Dam and the preparation of the contracts and contract plans."

On November 21, 1888, Mr. Fteley was appointed Chief Engineer of the Aqueduct Commission, and continued in this position until failing health made it necessary for him to resign, at the end of 1899. While occupying this position, Mr. Fteley had charge of the design and construction of very important works, including the Jerome Park Reservoir and the New Croton and other dams upon the Croton River and its branches. All of these, except the Jerome Park Reservoir and the New Croton Dam, were completed before his resignation and successfully stood the test of actual use.

As there have been criticisms regarding the selection of the site of the New Croton Dam, it is well to state that Mr. Fteley, in

a report to the Aqueduct Commissioners, dated October 8, 1890, advised the building of a dam farther upstream, and not at this place, but his advice was not followed.

In addition to the important permanent positions which have been mentioned, Mr. Fteley had a large consulting practice in connection with water supplies, sewerage and otherwise. Among the more important positions held were those of member of the Technical Advisory Committee of the new Panama Canal Company, Consulting Engineer for the Metropolitan Water and Sewerage Board of Massachusetts, for the first Rapid Transit Commission of Boston, and in connection with the additional water supplies of Newark, N. J., and Rochester, N. Y.

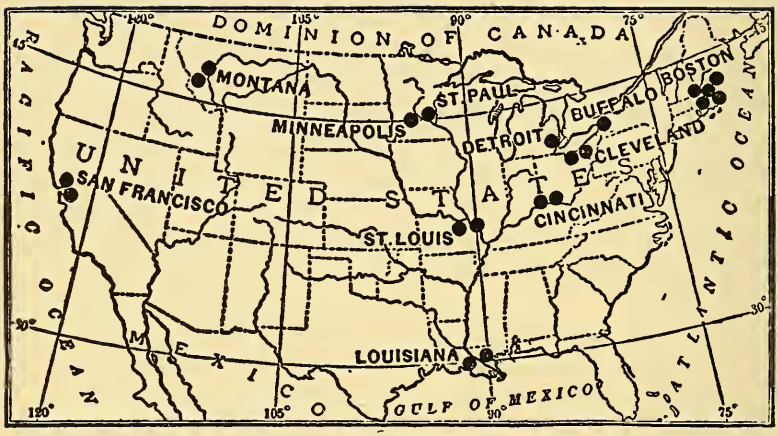
Mr. Fteley joined the Boston Society of Civil Engineers on June 8, 1874, and, notwithstanding his absence from Boston for the nineteen years preceding his death, he retained his membership and his interest in the Society. He joined the American Society of Civil Engineers in 1876, and was its President in 1898. He was elected a member of the New England Waterworks Association in June, 1885, and was made an honorary member in September, 1902. He received the degree of Master of Arts from Columbia University in 1898. He was a member of the Century Club of New York.

After retiring from active practice Mr. Fteley's failing health required him to avoid all physical exertion, but his mental powers remained undiminished and he attended to a limited amount of consulting work.

On May 19, 1898, Mr. Fteley met with a very great loss in the death of his wife. He leaves one daughter, Miss Estelle Fteley, and four stepchildren, Miss Marie Breuchaud and Jules Breuchaud, of Yonkers, N. Y.; Mrs. George S. Rice, of New York City, and Mrs. Andrew Cunningham, of Oakland, Cal.

He possessed natural ability of a high order and was thoroughly educated for his profession; he entered upon the study of any problem presented to him with unbiased mind, and, having the power of close and continued reasoning, he reached conclusions that were sound. Naturally, with these attributes, he achieved a high rank in his profession, and stood among the foremost in his specialty of hydraulic engineering. Being endowed with a very equable and sympathetic temperament and having pleasing manners and address, he won the warm and lasting regard of all with whom he was brought in association—those for whom he worked as well as those who worked with and under him. His character was altogether admirable.

Joseph P. Davis,
Frederic P. Stearns,
George S. Rice,
Committee.


DOMINION OF CANADA
MONTANA
ST PAUL
BUFFALO
BOSTON
MINNEAPOLIS
DETROIT
CLEVELAND
SAN FRANCISCO
CINCINNATI
ST. LOUIS
LOUISIANA
MEXICO
GULF OF MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN
120°
105°
90°
75°
30°

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XXXI. JULY, 1903. No. 1.

PROCEEDINGS.

Technical Society of the Pacific Coast.

REGULAR MEETING, SAN FRANCISCO, CAL., JUNE 5, 1903.—Called to order at 8.30 o'clock P.M., by President Henny.

The minutes of the last regular meeting were read and approved.

The following named persons were elected to membership after a count of ballots:

Member—Charles List, civil engineer.

Associates—George Stone, President Portland Cement Company, San Francisco, Cal.; Rudolph J. Taussig, President Mechanics' Institute, San Francisco, Cal.; S. Giletti, contractor, San Francisco, Cal.

Mr. Marsden Manson and Mr. C. E. Grunsky discussed the various projects for a water supply for the city of San Francisco, relating in some detail the present means of the Spring Valley Waterworks and the probable methods of increase in the supply with the growth of the city. The projects of a municipal waterworks on a large scale, with water brought from the Sierras, was fully discussed and the advantages of such an attractive supply brought out.

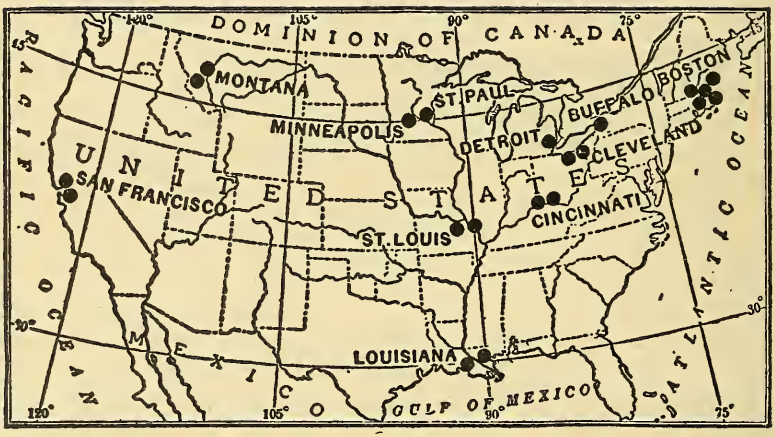
President Henny discussed the proposition from an economic standpoint, and thought that the vast storage of the lower San Joaquin and Sacramento Rivers might be drawn on for an ample and healthful supply, and that with facilities for a proper filtration there appeared no reason why this supply, so favorably situated, should not be utilized.

His remarks were not offered as a criticism, but were in the nature of suggestions to draw out a discussion in this particular line of argument.

This important subject was discussed at length by a number of the members, until, at a late hour, the Society adjourned.

The announcement was made officially that, according to custom, the regular July meeting would be dropped on account of the summer holidays.

OTTO VON GELDERN, *Secretary.*


DOMINION OF CANADA
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MEXICO
GULF OF MEXICO
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ATLANTIC OCEAN
120°
105°
90°
75°
30°

Association of Engineering Societies.

Vol. XXXI. **August, 1903.** No. 2.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, San Francisco, Cal., August 7, 1903.—Called to order at 8.30 P.M. by Past President Grunsky. The minutes of the last regular meeting were read and approved.

Mr. C. E. Grunsky addressed the members informally, taking for his subject the impressions made upon him by the engineering works of the Eastern states while visiting them recently. He described with much detail some of the principal structures visited, such as the Croton Dam, and gave some very interesting information about them. His subjects were illustrated by a great many photographs taken by himself, which, during his discourse, were passed around to the members.

It was announced subsequently that one of the charter members of the Technical Society, George F. Allardt, died at his residence in Oakland several days ago. The Secretary sent an appropriate floral offering in the name of the Society, and has received the following answer:

To the Technical Society:

Accept my thanks for the beautiful wreath of maidenhair fern and roses sent by the Society, as it expressed to me the high esteem in which Mr. Allardt was held. Respectfully yours,

Mrs. G. F. Allardt.

Sunday, August 9th.

The Secretary has also reported to the Board of Directors that he had communicated with a member of the family for a history of the deceased engineer, which is to be published as an appropriate memorial in the Journal of the Association of Engineering Societies. This will be placed before the Society as soon as it has been received by the Secretary.

It likewise became the sad duty of the Secretary to report to the Board of Directors the death of our fellow-member, Frank B. Morse, who died in the city of Mexico on February 18, 1903, where he was taken early in the November previous, suffering from complications that resulted in cirrhosis of the liver, of which he died. He was 51 years and 3½ months old. At the time of his illness he was the superintendent of the Corejo Colorado Mines and Mill at Ocatlan, and had also under lease other mining

and mill properties at El Parian. He left a wife, two daughters—one the wife of Mr. Chas. H. Andros—and a young son. The widow now resides at Gloucester, Mass.

Mr. Morse was a charter member, and is probably known only to those who were members in the early history of the Society. Although in a foreign country for many years, he always kept in touch with the Technical Society and its members, who will regret the loss of one so loyal and faithful to them.

Without further business the meeting adjourned.

Otto von Geldern, *Secretary.*

Association of Engineering Societies.

Vol. XXXI. **September, 1903.** No. 3.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, Mass., September 16, 1903.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock P.M.; President Ira N. Hollis in the chair. Forty-five members and visitors present.

The record of the last meeting was read and approved.

On motion of Mr. Adams, the thanks of the Society were voted to Lieutenant-Colonel W. S. Stanton, U. S. A., Lighthouse Engineer, and to Mr. Royal Luther, Superintendent of Construction; also to the Hon. James Donovan, Superintendent of Streets of Boston, and to chief clerk, Mr. W. J. Sheils, for courtesies extended to members of the Society on the excursion of August 22, 1903, to "Boston Light" and to the new lighthouse under construction at "The Graves."

The Secretary read a communication from the Committee of the American Society of Civil Engineers on Universal Exposition at St. Louis in 1904, extending to the members of this Society a cordial invitation to avail themselves of the conveniences of the headquarters to be established by the American Society at St. Louis during the Exposition. The Secretary was directed to acknowledge the receipt of the communication and express the thanks of the Society for the courtesy extended.

Communications were read from Mr. W. P. Morse and G. A. Nelson, members of the Society, submitting designs for a Society badge.

A general discussion followed on the advisability of the adoption of a badge by the Society, and, on a motion, the sense of the meeting was taken, which was almost unanimous in favor of the adoption of a badge. It was finally voted that the Board of Government issue a letter ballot on the question of the adoption of a badge and calling for an expression of the preferences of members among the five designs already submitted, or for others which may be submitted. The Secretary was also instructed to have sample badges made of the two designs presented at this meeting.

Mr. William O. Webber then read the paper of the evening, entitled "Rainfall and Runoff of New England and Atlantic Coast Streams." An interesting discussion followed, in which Messrs. Charles T. Main, Richard A. Hale, Dwight Porter, Freeman C. Coffin and Lewis M. Hastings took part.

Adjourned. S. E. Tinkham, *Secretary.*

Engineers' Club of St. Louis.

565TH MEETING, ST. LOUIS, SEPTEMBER 16, 1903.—Held at the Club Rooms, 709 Pine street, at 8.15 P.M.; Vice-President Ockerson in the chair. Present twenty-three members and four visitors.

The minutes of the 564th meeting were read and approved.

The minutes of the 350th and 351st meeting of the Executive Committee were read.

The applications for membership of Messrs. F. C. Albrecht, Edw. B. Day, John V. Hanna and E. F. Wiederholdt were read and referred to the Executive Committee.

The death of Mr. Edmund D. Libby, who died April 24th, at Concord, N. H., was announced.

The Secretary then read a letter from Mr. R. H. Phillips, informing the Club that the Engineering Association of the South intended to hold its annual meeting at St. Louis during the World's Fair. It was moved, seconded and carried that the Secretary be instructed to invite the said Association to make use of the Club's headquarters during its stay in St. Louis.

The paper of the evening, by Mr. Percival E. Fansler, on the "Indiana Interurban Systems," was then read. The paper was illustrated by a number of charts and sketches, and dealt principally with the power generation and transmission features of the system, with special reference to some very exhaustive tests of the economy of the generating and transmission systems. It was found that about 3.5 per cent. of the energy in the coal reached the car, while about 53 per cent. of the energy delivered to the generators reached the car. The longest transmission on the system is thirty-three miles.

The paper was very generally discussed by the members present, after which a vote of thanks was tendered Mr. Fansler for his instructive discourse.

Upon motion the meeting adjourned to the lobby, where a light lunch was served.

H. J. PFEIFER, *Secretary.*

ASSOCIATION OF ENGINEERING SOCIETIES.

VOL. XXXI. OCTOBER, 1903. No. 4.

PROCEEDINGS.

Boston Society of Civil Engineers.

BOSTON, OCTOBER 21, 1903.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock P.M.; President Ira N. Hollis in the chair. Ninety-two members and visitors present.

The record of the last meeting was read and approved.

Messrs. Harold W. Horne and James W. Pierce were elected members of the Society.

The President announced the death of William C. Ogden, a member of the Society, which occurred on October 12, 1903, and on motion the President was requested to appoint a committee to prepare a memoir.

The President has appointed as this committee Messrs. S. Foster Jacques and Arthur W. Dean.

The thanks of the Society were voted to Professor Hollis, Professor Johnson and Mr. Wason for courtesies extended to members on the occasion of the visit to the stadium under construction on Soldiers' Field for Harvard College.

Mr. Kimball, for the committee appointed to revise the By-laws of the Society, submitted the following report:

BOSTON, October 1, 1903.

To the Boston Society of Civil Engineers:

Your committee on revision of the By-laws respectfully report as follows:

We recommend the following amendments to the By-laws:

Strike out Section 5 and substitute therefor the following:

5. NOMINATION AND ELECTION OF OFFICERS.—A nominating committee of eleven shall be chosen at the regular meeting in December. Two of the members of the committee shall be the two most recent living past-presidents; the other nine members shall be chosen by letter-ballot, each member of the Society voting for one member of the committee on a card to be furnished by the Secretary with the notice of the December meeting; this card to contain a list of members ineligible for the committee. The nine eligible members receiving the highest number of votes shall be declared elected; and in case of a tie the choice between the members so tied shall be determined by lot. In case any member shall refuse to serve, the member receiving the next highest number of votes shall be declared elected.

No officer of the Society shall be eligible to membership on the committee, and no member, other than the two past-presidents referred to above, shall be eligible to serve on the committee in successive years.

The nominating committee shall meet at the call of the senior of the two past-presidents; and seven members shall constitute a quorum. It shall submit to the Secretary, within twenty days after the December meeting, the name of one candidate for each office to be filled by ballot at the annual meeting. The Secretary shall send to

each member of the Society, not later than January 20th, a copy of the nominations made by the committee.

At any time previous to February 5th, any ten or more members may submit to the Secretary additional nominations, signed by such members, and accompanied by acceptances from the members so nominated.

Letter-ballots shall be sent by the Secretary to each member of the Society, at least thirty days before the day of the annual meeting, stating the hour at which the polls will close on that day. These ballots shall contain the nominations submitted by the nominating committee and also all additional nominations made in accordance with the terms of the preceding paragraph, in alphabetical order and without any designation to indicate the manner in which candidates have been nominated. Each ballot shall be returned to the Secretary inclosed in two sealed envelopes, the inner one to be blank and the outer to be indorsed with the member's signature. The President shall appoint two tellers, who shall canvass all ballots, and the result shall be announced at the annual meeting.

Of the candidates for any office, the one having the largest number of legal votes by letter-ballot shall be elected. Should there be a failure to elect any officer on account of a tie, the meeting shall proceed to elect such officer by ballot from among the candidates so tied; a majority of the votes cast being required to elect.

Vacancies occurring in any office may be filled by ballot at the first meeting after notice of the same has been sent to each member; a majority of the votes cast being necessary to elect.

Add at the end of Section 6 the following:

The Librarian shall receive an annual salary of $50.

Amend Section 10 by striking out the last sentence of the first paragraph and substituting therefor the following:

New members shall not be liable for the annual dues for the year in which they are elected, and if elected after October 1, they shall be liable for only one half of the annual dues for the ensuing year, so as to read as follows:

10. Fees and Dues.—The entrance fee shall be ten dollars. The annual dues shall be eight dollars for members and associates residing within thirty miles of Boston, and five dollars for those residing at a greater distance, payable in advance at the annual meeting. New members shall not be liable for the annual dues for the year in which they are elected, and if elected after October 1, they shall be liable for only one-half of the annual dues for the ensuing year.

The Board of Government may deduct the cost of the Journal from the dues of members who receive said Journal from other sources.

If the annual dues prove insufficient to meet the expenses of the Society, it may levy assessments on its members and associates not exceeding four dollars per person in any one year.

Add a new section, to be numbered 15, as follows:

15. Sections.—The Board of Government may from time to time, at its discretion, establish sections for the consideration of special branches of engineering. Such sections shall in all cases be known as "The [name] Section of the Boston Society of Civil Engineers."

Each section shall consist of not less than ten members of the Society, with such other persons as shall be elected by the section as its members after approval of their applications by the Board of Government.

Section members, who are not members of the Society, shall be entitled to attend all meetings and excursions, to use the library, and to receive the publications of the Society.

Papers and discussions may be reported in accordance with the section by-laws, and shall be published in the same manner and subject to the same conditions as obtain with respect to papers read before the Society.

All sections shall be governed by the Constitution and By-laws of the Society, so far as applicable, but they shall be entitled to make additional by-laws for their own use and government; *provided, however*, that said additional by-laws be not inconsistent with the Constitution and By-laws of the Society, and that they be approved by the Board of Government.

The general government of each section shall be vested in an Executive Committee, consisting of the President of the Society, and the Chairman, Vice-Chairman, Clerk and three additional members of the section.

The officers of each section, who shall be elected by it annually, shall be a Chair-

man, a Vice-Chairman, a Clerk, and three additional members of the Executive Committee.

The fees and dues for members of sections who are not members of the Society shall be: Entrance fee, $5 and annual dues, $5, which shall be paid to the Secretary of the Society. The dues for the remainder of the first fiscal year after date of election shall be remitted to members of sections.

Members or associates of the Society may, without election, become members or associates of any sections, under such regulations as may be prescribed by the by-laws of the sections, without the payment of additional fees or dues.

Any member of a section becoming a member of the Society shall pay the difference between the entrance fees of the Society and the section, but shall pay no dues to the Society for the remainder of the fiscal year after his election.

The Chairman of Sections shall be entitled to seats in the Board of Government, but without votes.

Any section may be abolished by the Society by a two-thirds vote at any regular meeting, upon recommendation of the Board of Government, due notice of such recommendation having been sent with the notice of the meeting to each member of the Society, and to each member of the particular section who is not a member of the Society; and all members of the particular section shall be entitled to be heard at this meeting.

Resignations, forfeiture of membership or expulsion of members of sections shall be governed by the same conditions and methods of procedure as apply to members of the Society.

Renumber the present Section 15, making it Section 16.

Respectfully submitted,

FREEMAN C. COFFIN, *Chairman.*
HENRY MANLEY.
GEORGE A. KIMBALL.
FRANCIS W. DEAN.
OTIS F. CLAPP.
EDWARD F. MILLER.
SIDNEY HOSMER.
CHARLES W. SHERMAN.
LEONARD METCALF, *Secretary.*

Mr. Manley dissents from so much of the foregoing recommendation as relates to the Nomination and Election of Officers (Section 5).

On motion of Mr. L. F. Rice it was voted to receive the report, and under the ruling of the chair this included the minority report of Mr. Manley.

After a discussion on the advisability of adjourning this meeting to a special date it was finally voted, on motion of Mr. Hodgdon, to make the consideration of the proposed amendments to the By-laws the special business at the next regular meeting, and that the Board of Government call a special meeting, if it deem it advisable, for the consideration of any literary exercises which would have been presented at the regular meeting.

It was also voted, on motion of Mr. Hodgdon, to print in the notice of the November meeting any additional amendments to the By-laws which may be sent to the Secretary.

President Hollis then gave a very interesting description of the concrete-steel stadium for Harvard College now under construction on the Soldiers' Field.

Adjourned.

S. E. TINKHAM, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, SAN FRANCISCO, SEPTEMBER 4, 1903.—Called to order at 8.30 o'clock P.M. by Director Stetson G. Hindes.

The minutes of the last regular meeting were read and approved.

Mr. James T. Ludlow, mechanical engineer, addressed the members on

the subject of "Methods of Refrigeration," which he illustrated by a number of fine lantern slides. The paper was one of extreme interest and caused a long discussion, bearing directly upon the various means of modern refrigeration.

The Chairman expressed to the author of the paper the appreciation of the Technical Society, whereupon the meeting adjourned.

OTTO VON GELDERN, *Secretary.*

REGULAR MEETING, SAN FRANCISCO, OCTOBER 2, 1903.—Called to order at 8.30 o'clock P.M. by Past President Marsden Manson.

The reading of the minutes of the last regular meeting was dispensed with, the Secretary explaining that the Record Book had been left at his office by an oversight.

The Secretary read a memorial to the late August H. Schierholz, member of the Technical Society, during the reading of which the Society remained standing. This memorial was ordered to be sent to the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES for publication, and that a number of copies be struck off independently for distribution among his immediate relatives and friends.

Mr. Geo. W. Dickie read a paper entitled, "Is It not Time to Consider whether Patent Laws are any Longer Necessary to Progress in the Mechanical Arts?"

This paper caused considerable discussion, the discussion to be continued at the next meeting, for which Mr. John Richards has promised a similar contribution by the following letter, which was read:

"I beg to state that I will, at any future time, designated by yourself or the Executive Committee, present a paper on 'The Influence of Patent Inventions on the Social, Economic and Industrial Interests of Our Time.' As such a paper may in some respects present different views from those contained in Mr. Dickie's paper, it may be proper to explain that I cannot confine my remarks to progress in mechanical engineering, not knowing whether *discovery* alone is meant thereby; hence have chosen the wider and perhaps cumbrous title."

The Secretary was instructed to communicate with Mr. Richards and to place at his disposal the evening of the November meeting for the purpose of receiving and discussing the subject from his standpoint.

The Chairman referred to the prosperous financial condition of the Society, calling attention to the fact that a surplus had gradually accumulated in the treasury, showing an encouraging state of affairs, which, however, seemed not borne out by the general attendance at meetings, which had fallen off considerably.

Mr. Dickie offered the explanation that the attendance is dependent upon the papers presented for discussion and debate. With an adequate number of subjects the members would attend regularly. He realized the difficulty of preparing elaborate papers for such frequent meetings as once a month, and suggested that meetings be held but twice or three times a year; that such meetings last several days, and that during such semi-annual or tri-annual meetings more extensive preparations be made; that six or eight papers properly prepared for such occasions be read and discussed by large assemblies, from all parts of the State, and that in this way a new and more

active interest be aroused, that would be impossible to keep up where meetings are held from month to month.

Most members appeared to agree with Mr. Dickie, and manifested a strong desire that this new departure be tried. If the constitution call for monthly meetings, these might be held as heretofore for topical discussion and business transactions, but that the main effort of the Society should be made and concentrated upon two prominent gatherings per year, for which ample preparation should be made, and sufficient time given to those members who had important technical communications to present to the Society.

A motion was made by the Secretary that the Chair appoint a committee of three to study the conditions and outline a plan of future Society meetings on the basis suggested by Past President Dickie, that a limited number of meetings be held per year for the purpose of reading and discussing professional papers, and to make these meetings an inducement for well-attended and energetic gatherings; this committee to report at the next regular meeting. This motion was carried.

Chairman Manson appointed on this committee the following: Past President Geo. W. Dickie, President D. C. Henry and Secretary Otto von Geldern.

The meeting thereupon adjourned.

OTTO VON GELDERN, *Secretary.*

Engineers' Club of St. Louis.

566TH MEETING, ST. LOUIS, OCTOBER 7, 1903.—Held at the Club rooms, 709 Pine Street, at 8.15 P.M., President Van Ornum in the chair.

Present, thirty-four members and seven visitors.

The minutes of the 565th meeting were read and approved.

The minutes of the 352d meeting of the Executive Committee were read.

The application for membership of Mr. L. V. Vella was read and referred to the Executive Committee.

The following gentlemen were, on ballot, unanimously elected to membership: F. C. Albrecht, Edward B. Day, J. V. Hanna and E. F. Wiederholdt.

The Secretary read a letter from the Engineering Association of the South, thanking the Club for the tender of the use of its Club rooms during the coming convention of the Engineering Association of the South in St. Louis.

A vote of thanks was given to Messrs. Robert Moore and S. E. Freeman for contributions to the library.

The paper of the evening, by Mr. A. P. Greensfelder, on "Some Proposed Improvements in St. Louis Terminal," was then read. The author confined his remarks to improvements along the lines of the Terminal Railroad Association of St. Louis. He gave interesting descriptions of the work being done by this company in providing increased facilities to adequately take care of the rapidly growing commerce of St. Louis. He showed what improvements were under way at all points of the system, and how they would help to relieve the present congestion due to inadequate facilities. The subway work, track changes, interlocking plant and power house for the Union Station were described with some detail, and showed that the

Terminal Association was expending large sums of money on its increased facilities. The paper was discussed by Messrs. Hermann, Van Ornum, Johnson and Humphry, after which the meeting adjourned.

H. J. Pfeifer, *Secretary.*

567th Meeting, St. Louis, Mo., October 21, 1903.—A regular meeting of the Engineers' Club of St. Louis was held at the Club rooms, 709 Pine Street, on Wednesday evening, at 8.15 P.M.; President Van Ornum in the chair. Thirty-one members and three visitors present.

The minutes of the 566th meeting were read and approved.

The minutes of the 353d meeting of the Executive Committee were read.

The applications for membership of Messrs. J. F. Hinckley and W. E. Rolfe were read and referred to the Executive Committee.

The chair announced that the American Society for the Advancement of Science would hold a convention in St. Louis in January, 1904, and that the committee in charge of the convention was desirous of having the Engineers' Club of St. Louis participate in entertaining the members of this Society. It was moved by Mr. Russell, seconded and carried, that the President appoint a committee of three to co-operate with other committees in the entertainment of the members of the American Society for the Advancement of Science. The President appointed Messrs. S. B. Russell, R. H. Fernald and A. P. Greensfelder to serve on the committee.

It was moved by Mr. Hermann, seconded and carried, that the recommendation of the Executive Committee relative to the participation of the Club in the World's Fair be adopted, and that the Executive Committee be empowered to make the necessary arrangements.

The paper of the evening, by Mr. W. M. Carr, chief chemist of the American steel foundries, at East St. Louis, Ill., on the "Heat Treatment of Steel," was then read. Mr. Carr's paper was illustrated by lantern slides, and showed the great care that is being taken in the modern steel foundries to turn out reliable material. He showed how the temperature to which the metal is subjected and its rate of cooling effects its durability and hardness. The paper was discussed by Messrs. Russell, Langsdorf, Phillips, Mitzger, Van Ornum, Wheeler, Kessler, Hermann, Freeman, Greensfelder and Hanna.

A vote of thanks was unanimously tendered Mr. Carr for his kindness in addressing the Club, after which the meeting adjourned to the lobby, where a light luncheon was served.

H. J. Pfeifer, *Secretary.*

Association of Engineering Societies.

Vol. XXXI. **November, 1903.** No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

568th Meeting, November 4, 1903.—The meeting was held at the Club rooms, 709 Pine Street, at 8.15 P.M.; President Van Ornum in the chair. Twenty-one members and three visitors were present.

The minutes of the 567th meeting were read and approved.

The minutes of the 354th and 355th meetings of the Executive Committee were read.

The following gentlemen, who were on ballot, were unanimously elected to membership: J. F. Hinckley, W. E. Rolfe and L. B. Vella. In accordance with the By-laws the Club then proceeded to elect a Nominating Committee, to nominate officers of the Club for the ensuing year.

The following were put in nomination as members of the Nominating Committee: A. H. Zeller, F. C. Bausch, Gerard Swope, A. S. Langsdorf, Wm. H. Bryan, Hans Toensfeldt and Edward Flad. Of these Messrs. Zeller, Flad, Langsdorf, Swope and Bryan were elected.

The President then read a letter from His Honor Rolla Wells, Mayor of the city of St. Louis, asking the Club to solicit subscriptions for an appropriate gift to the battleship "Missouri." It was moved and seconded that the chair appoint a committee of three to comply with the request of the Mayor.

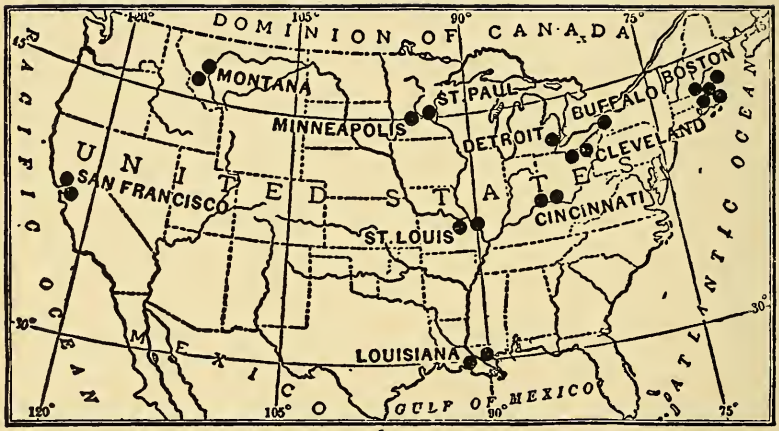
The chair appointed on this committee Messrs. Layman, Pitzman and R. H. Phillips.

It was decided to have at the next meeting of the Club, as a special order of business, a discussion as to the advisability of discontinuing the awarding of the annual prize for the best paper read during the year.

The paper of the evening, by Prof. R. H. Fernald, on "Methods for Determining the Temperature of Gas Engine Exhaust," was then read. The author outlined a number of interesting experiments made by himself in the laboratory of the Columbia University in New York city. The paper was illustrated by a number of diagrams and other illustrations. The paper was afterwards discussed by Messrs. Hazzard, Freeman and Layman, after which the committee adjourned to the lobby, where a light luncheon was served.

Adjourned.

H. J. Pfeifer, *Secretary.*


DOMINION OF CANADA
MONTANA
ST. PAUL
MINNEAPOLIS
BUFFALO
BOSTON
DETROIT
CLEVELAND
SAN FRANCISCO
CINCINNATI
ST. LOUIS
LOUISIANA
GULF OF MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN
MEXICO
120°
105°
90°
75°
30°

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XXXI. **DECEMBER, 1903.** No. 6.

PROCEEDINGS.

Technical Society of the Pacific Coast.

REGULAR MEETING, SAN FRANCISCO, CAL., NOVEMBER 6, 1903.—Called to order at 8.30 P.M. by Past-President Manson.

In the absence of the Secretary, Mr. C. E. Grunsky was called upon to act in his stead.

The minutes of the last two regular meetings, September and October, were read and approved.

The committee appointed at the last regular meeting on the proposed amendment to the By-laws, relating to Stated Meetings and their most practical frequency, handed in a report, which was read as follows:

To the Technical Society of the Pacific Coast:

Your committee, appointed at the last regular meeting of October, to whom was referred the matter of the frequency of Society meetings for reading and discussing technical papers, has given this subject the fullest consideration, and begs to report as follows:

We believe that better results could be obtained if, instead of meeting regularly from month to month, only two general meetings for the year were held, one in the spring and one in the autumn.

The constitution of the Society does not specify how often meetings shall be held. This is regulated by Section 2, Article I, of the By-laws, which provides that the regular "Stated Meetings of the Society shall be held on the first Friday of each month."

It will not be difficult to amend this particular Section should the Society consider our recommendation worthy of approval, for the By-laws may be amended at any regular meeting by the vote of the majority of the members present, provided that at least seven votes be cast in favor of the amendments, and that notice of such proposed amendments shall have been presented in writing at the previous regular meeting.

The one main difficulty the Society has had to contend with—not only this, but all societies of a similar character—is to provide papers on technical subjects; while in the earlier history of an organization the enthusiasm may bring forth subject-matter for a long-continued season, experience has taught that the spirit of apathy is sure to follow, and the difficulty of obtaining

papers becomes more and more formidable. To ask for them is like asking for a special favor, and this must be all the more apparent if the stated meetings repeat themselves at frequent intervals. With a lack of papers follows a lack of interest and, in consequence, a lack of attendance, and the prospective author is all the more reluctant to address a meeting consisting of a few members on a subject that may involve considerable trouble, time and expense. It is reasonable to expect appreciation for an earnest and sincere effort, and it is but a natural result to see the work among our members in that direction fall off from year to year.

We propose to better these conditions by making each meeting of the Society an event, but in order to carry out a program of an extensive character successfully, the meetings should not be held more than twice during the course of the year; that is, meetings for reading and discussing prepared papers on technical subjects. This need not exclude monthly meetings for the transaction of business or for the informal discussion of any subject that may appear to be of immediate interest. But the formal meetings, convened for the improvement of members and the advancement of the technical professions, should be concentrated to not more than two systematically arranged meetings per year. For these occasions the papers should be prepared in the preceding six months and should have passed through the hands of the proper committee and approved for admission into a prearranged program.

These meetings should not be confined to one evening, but, announced as semi-annual gatherings of the Society, they should last for two days and nights. The program might include visits incorpore to points of interest and social meetings in the nature of public receptions or dinners; these are matters of detail that are easily arranged subsequently if we are finally agreed upon such a radical change as the one now proposed.

By making each meeting an event it will not be difficult to draw visitors from all parts of the State and from all the local members of the great American Societies, many of whom are members of the Technical Society of the Pacific Coast.

Now, then, in order to facilitate matters and to obtain the sense of our members on this proposed change, your committee begs to offer the following amendments to the By-laws:

Strike out Section 2, Article I, of the By-laws, which reads:

"Sec. 2. The regular Stated Meetings of the Society shall be held on the first Friday of each month, at the Hall of the Society, at 8 P.M."

and substitute therefor:

Sec. 2. The regular Stated Semi-annual Meetings of the Society shall be held on the first Friday and Saturday of the month of March and on the first Friday and Saturday of the month of September of each year, according to an arranged program provided by the Executive Committee of the Board of Directors, and for the purpose of reading and discussing technical papers, as well as for stimulating professional and social intercourse among members.

Amend Section 3, Article I, by placing before the present Section the following words:

Monthly stated meetings may be held on the first Friday of any month for the transaction of the ordinary business of the Society and for informal topical discussions.

And it is further amended to strike out all of Section 5, Article I, which would be in conflict with Section 2 as now amended.

We would recommend that this report be accepted as a written notice of the proposed amendments to the By-laws, that it be referred to the Board of Directors for its approval or for such modification as may be necessary to avoid conflict with any other section now existing, that the Board of Directors report back the proposed amendments ratified and approved at the regular December meeting, and that at that meeting they be submitted to the vote of the Society according to Aricle X of the By-laws.

We feel confident that changes on these lines will awaken an interest in the Society, which has lost the hold upon its members for no other reason than that it could not supply its frequent meetings with technical subjects properly prepared. Let it be known that hereafter each semi-annual meeting will be made a technical event in San Francisco, and we are sanguine that the Society will regain its former popularity and will become a factor in the consideration of technical affairs in the city of San Francisco and in the State of California. There is a want and a field of operation for a technical organization in this community, and how to make its influence best felt has been the object of the changes herein proposed.

Respectfully submitted,

GEO. W. DICKIE,
D. C. HENNY,
OTTO VON GELDERN,
Committee.

On motion the recommendations made by the committee were adopted. The amendments are to be considered introduced and read, and are to be voted upon at the next regular meeting, in accordance with Article X of the By-laws, which provides that any proposed amendment shall have been presented in writing at any regular meeting, and that at the meeting following the reading such proposed amendment may be approved by the vote of the majority of the members present; at least seven votes must be cast in favor of such amendment.

The Secretary read a report presented by the committee instructed to write a fitting memorial to the late George F. Allardt, member Technical Society, which was ordered to be published in the JOURNAL and spread in full upon the minutes.

The paper of the evening was read by Past-President John Richards, entitled "The Administration of Patent Laws." This was followed by a discussion in which Mr. Geo. W. Dickie was the principal speaker, who complimented Mr. Richards on the logical presentation of the subject and stated that he fully agreed with him in the position taken and in the line of the produced argument.

The following applications for membership were made: Joseph Jacobs, civil engineer, San Francisco; proposed by Chas. B. Wing, John H. Wallace and Otto von Geldern. Robert Hauxhurst, civil engineer, Hilo, Hawaii; referred to Chas. H. Kluegel, E. F. Haas, J. J. Hollister, Norman B. Livermore and Chas. D. Marx.

The applications were referred to the Board of Directors for approval, with instruction to proceed to ballot if found satisfactory.

Adjourned.

C. E. GRUNSKY, *Secretary pro tem.*

Boston Society of Civil Engineers.

BOSTON, NOVEMBER 18, 1903.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M.; Vice-President Frederick Brooks in the chair. Fifty-six members and visitors present.

The record of the last meeting was read and approved.

Mr. Frank T. Daniels was elected a member of the Society.

The chair announced the death of Frank P. Johnson, a member of the Society, which occurred on November 1, 1903. On montion, the President was requested to appoint a committee to prepare a memoir. The President has named the following as members of that committee, Bertram Brewer and Joseph R. Worcester.

The Board of Government submitted a report, giving the result of the informal ballot on the question of adopting a badge and on the expression of the preferences of members among the several designs submitted.

The meeting then took up the question of the adoption of a Society badge, and after a general discussion on the preference among the five designs, as shown by the informal letter-ballot, it was voted to adopt a Society badge.

The discussion was then continued upon the advisability of submitting to a formal letter-ballot the selection of a badge, but upon a vote being taken the Society declined to issue such a ballot.

The Society then voted to adopt as its badge the design here shown and substantially in accordance with the sample presented at the meeting.



On motion, the Board of Government was authorized to arrange for the manufacture and sale of the badges.

The amendments to the By-laws, as presented at the last meeting by the Committee on Revision, was then taken up. On motion of Professor Allen, it was voted to amend By-law 6, by adding at the end the words "The librarian shall receive an annual salary of $50." Fifty voted in favor and none against, and the amendment was adopted.

On motion of Mr. Howe, it was voted to amend By-law 10, so as to read:

FEES AND DUES.—The entrance fee shall be ten dollars. The annual dues shall be eight dollars for members and associates residing within thirty miles of Boston, and five dollars for those residing at a greater distance, payable in advance at the annual meeting. New members shall not be liable for the annual dues for the year in which they are elected, and if elected after October 1st, they shall be liable for only one-half of the annual dues for the ensuing year.

The Board of Government may deduct the cost of the JOURNAL from the dues of members who receive said JOURNAL from other sources.

If the annual dues prove insufficient to meet the expenses of the Society, it may levy assessments on its members and associates not exceeding four dollars per person in any one year.

Forty-six voted in favor and six against, and the amendment was adopted.

It was then voted to proceed to the consideration of the proposed by-law, numbered 15, in the committee's report. It was also voted to take up the matter paragraph by paragraph.

After a prolonged discussion the several paragraphs were adopted in the following form:

SECTIONS.—The Board of Government may from time to time, at its discretion, establish sections for the consideration of special branches of engineering. Such sections shall in all cases be known as "The [name] Section of the Boston Society of Civil Engineers."

Each section shall consist of not less than ten members of the Society, with such other persons as shall be elected by the section as its members after approval of their applications by the Board of Government.

A member of a section, who is not otherwise a member of the Society, shall be entitled to attend all meetings and excursions, to use the library and to receive the publications of the Society, to take part in the discussions of any papers on professional subjects or of any business affecting his particular section at any such meeting, but shall have no vote, except in his section.

Papers read before sections and discussions thereon may be reported in accordance with the section by-laws, and shall be published in the same manner and subject to the same conditions as obtain with respect to papers read before the Society.

All sections shall be governed by the Constitution and By-laws of the Society, so far as applicable, but they shall be entitled to make additional by-laws for their own use and government; *provided, however*, that said additional by-laws be not inconsistent with the Constitution and By-laws of the Society, and that they be approved by the Board of Government.

The officers of each section shall be a chairman, vice-chairman and clerk, who shall be elected by the members of the section annually.

The general government of each section shall be vested in an Executive Committee, consisting of the President of the Society, the officers of the section and three additional members of the section, who shall be elected annually.

The fees and dues for members of sections who are not members of the Society shall be: Entrance fee, $5; annual dues, $5; which shall be paid to the Secretary of the Society. The dues for the remainder of the first fiscal year after date of election shall be remitted to members of sections.

Members or associates of the Society may, without election, become members or associates of any section, under such regulations as may be prescribed by the by-laws of the sections, without the payment of additional fees or dues.

Any member of a section upon becoming a member of the Society shall pay the difference between the entrance fees of the Society and the section but shall pay no dues to the Society for the remainder of the fiscal year after his election.

The chairmen of sections shall be entitled to be present at the meetings of the Board of Government, but without votes.

Any section may be abolished by the Society by a two-thirds vote of all the members present at any regular meeting upon recommendation of the Board of Government due notice of such recommendation having been sent with the notice of the meeting to each member of the Society, and to each member of the section in question who is not a member of the Society; and all members of the section in question shall be entitled to be heard at this meeting.

Resignations, forfeiture of membership, or expulsion of members of sections shall be governed by the same conditions and methods of procedure as apply to members of the Society.

Under a ruling of the chair, that the amendments in their present form had not been presented at the previous meeting and therefore could not be adopted at this meeting, final action went over to the next meeting.

Messrs. E. W. Howe and J. H. Kinealy each proposed in writing amendments to By-law 5, in relation to the nomination and election of officers.

Mr. Hodgdon stated that in order to prevent any question in regard to By-law 15, of the report of the Committee on Revision of By-laws as

amended at this meeting, being in order for consideration at the next meeting, he would present the section in due form at this time.

Adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, DECEMBER 8, 1903.—A special meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M.; President Ira N. Hollis in the chair. One hundred and thirty members and visitors present.

Prof. L. J. Johnson read the paper of the evening, entitled "Prominent Features in the Design of the Steel-Concrete Work of the Harvard Stadium." The paper was illustrated with numerous lantern views.

Prof. Charles L. Norton, of the Massachusetts Institute of Technology, followed with a short paper, describing some experiments on the protection of steel in concrete from rust.

Prof. Gaetano Lanza gave the results of some tests made at the Institute of Technology on concrete-steel beams and columns, and showed by lantern views some of the specimens tested.

Prof. A. W. French, of the Worcester Polytechnic Institute, described some of the methods used in erecting the stadium, and Professor Norton, in answer to an inquiry, gave the results of some experiments on the rusting of steel embedded in concrete.

After passing a vote of thanks to Professors Norton and French, for their interesting contributions to the evening's discussion, the Society adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, MASS., DECEMBER 16, 1903.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.40 o'clock P.M.; Vice-President Frederick Brooks in the chair. Thirty-five members present.

The records of the last regular meeting and that of the special meeting of December 8th were read and approved.

After a short discussion, on motion of Mr. Hodgdon, the new by-law, marked Section 15, in the report of the Committee on Revision, as amended at the last meeting and printed in the notice of this meeting, was adopted, twenty-three voting in favor and five against its adoption.

It was also voted unanimously to renumber the present Section 15, making it Section 16.

Mr. Cheney, for the Committee on Amendments to Boston Building Laws, submitted the following report:

The Committee on Amendments to Boston Building Laws would recommend the following amendments to the present laws:

SECTION 19. Immediately before table of "*Deflection.—Modulus of Elasticity*" insert the following:

Shearing and bearing stresses on bolts whether wrought iron or steel shall be not higher than allowed by the above table for wrought iron. All connections in skeleton buildings of which the height exceeds twice the least horizontal dimension, all joints in steel trusses and girders and all connections of such trusses and girders to the sides of steel columns, shall be made by means of rivets.

SEC. 19. Amend paragraph beginning "Stresses for Steel," so that it will read:

Stresses for steel are those for "*Structural Steel*," having an ultimate tensile strength of 55,000 to 65,000 pounds per square inch, an elastic limit of not less than one-half the ultimate strength, and a minimum elongation in 8 inches of 1,400,000 divided by the ultimate strength, per cent.

SEC. 19. Amend the figure for the extreme fiber stress in cast iron in tension by increasing from *2500 to 3000.*

SEC. 19. In headings under both "*Stonework*" and "*Brickwork,*" after the word "Stresses." insert the words "*in compression.*"

SEC. 19. After the portion devoted to brickwork, insert the following:

CONCRETE.

When the structural use of concrete is proposed, a specification, stating the quality and proportion of materials, and the method of mixing thereof, shall be submitted to the Building Commissioner, who may issue a permit at his discretion and under such further conditions as he sees fit to impose.

In first-class Portland cement concrete containing one part cement, to not exceeding nine parts properly graded stone and sand, except in piers or columns of which the height exceeds six times the least dimension, the compressive stress shall not exceed thirty tons per square foot.

In piers and columns of first-class Portland cement concrete, containing one part cement to not exceeding seven parts properly graded stone and sand, where the height of pier or column is more than six times and does not exceed twelve times its least dimension, the compressive stress shall not exceed twenty-five tons per square foot.

In steel-concrete beams or slabs subjected to bending stresses, the entire tensile stress shall be carried by the steel, which shall not be strained above the limits allowed for this material. First-class Portland cement concrete in such beams or slabs, composed of one part cement to not exceeding seven parts of properly graded stone and sand, may be strained in compression not exceeding 500 pounds per square inch. In case one part of cement to not exceeding four parts of properly graded aggregate is used, this stress may be increased to not exceeding 600 pounds per square inch. Concrete shall not be strained in shear more than 50 pounds per square inch.

SECTION 23. After "iron," where it first occurs, omit the words, "*or steel,*" and insert "*steel or concrete-steel,*" and after "masonry arches," insert "*or concrete-steel slabs.*"

SEC. 27. After "covers," in third line from end, insert "*or with first-class Portland cement concrete containing one part of cement to not exceeding nine parts of properly graded stone and sand, the concrete to be filled in around the pile heads upon the intervening earth.*"

SEC. 30. In the third line, after "nineteen," insert "*or Portland cement concrete as provided in Section 27.*"

SEC. 30. Between lines 15 and 16, after "foundations of brick," insert "*or concrete.*"

SEC. 55 to be amended to read as follows: All new or renewed floors shall be so constructed as to carry safely the weight to which the proposed use of the building will subject them, and every permit granted shall state for what purpose the building is designed to be used; but the least capacity per superficial square foot, exclusive of materials, shall be:

For floors of dwellings and for apartment floors of apartment and public hotels, fifty pounds.

For office floors and for public rooms of apartment and public hotels, one hundred pounds.

For floors of retail stores, and public buildings, except schoolhouses, one hundred and twenty-five pounds.

For floors of schoolhouses, other than floors of assembly rooms, eighty pounds, and for floors of assembly rooms, one hundred and twenty-five pounds.

For floors of drill rooms, dance halls and riding schools, two hundred pounds.

For floors of warehouses and mercantile buildings, at least two hundred and fifty pounds.

The loads for floors not included in this classification shall be determined by the Commissioners, subject to appeal, as provided by law.

The full floor load specified in this section shall be included in proportioning all parts of buildings designed for dwellings, hotels, schoolhouses, warehouses, or for heavy mercantile and manufacturing purposes. In other buildings, however, certain reductions may be allowed, as follows: In girders carrying more than 100 square feet of floor, the live load may be reduced by 10 per cent. In columns, piers, walls, and other parts carrying two floors, a reduction of 15 per cent. of the total live load may be made; where three floors are carried, the total live load may be reduced by 20 per cent.; four floors, 25 per cent.; five floors, 30 per cent.; six floors, 35 per cent.; seven floors, 40 per cent.; eight floors, 45 per cent.; nine or more floors, 50 per cent.

Your committee would state that they have had the co-operation of the Committee

on Building Laws of the Boston Society of Architects and the Building Commissioner of the city of Boston, in the framing of the proposed amendments, and also their concurrence in the same.

Respectfully submitted,

JOHN E. CHENEY,
JOSEPH R. WORCESTER,
HENRY A. PHILLIPS,
Committee.

After a discussion, it was voted, on motion of Mr. Adams, that it is the sense of this meeting that the amendments to the Boston Building Laws proposed by the committee should be adopted, and that a copy of the report be presented to the Mayor of Boston with the vote of this meeting.

It was also voted to print the report in the notice of the next meeting, accompanied by the statement that it would come up for the Society's indorsement at that meeting, in accordance with Article V of the Constitution.

In the absence of any member of the committee appointed to prepare a memoir of our late associate, Alphonse Fteley, the Secretary read the memorial which the committee had prepared. It was voted to print the memoir in the JOURNAL.

Mr. Coffin voted to strike out Section 5 of the By-laws and substitute therefor the new by-law, Section 5, as submitted by the Committee on Revision at the October meeting. A long and earnest discussion followed, and at its conclusion the motion was lost, twelve voting in favor and eleven against the amendment, a two-thirds vote being required to amend a by-law.

Adjourned.

S. E. TINKHAM, *Secretary.*

Engineers' Club of Minneapolis.

169TH MEETING, MINNEAPOLIS, MINN., NOVEMBER 16, 1903.—The meeting was called to order by President Avery, in the County Commissioners' Room, Court House. About sixty members and friends were present. The following names were proposed for membership: F. D. Brown, T. S. Layman, H. A. Rogers, C. P. Howe, C. L. Dean, J. N. Pariseau, E. T. Hare, Jas. T. Keely, E. W. Ashenden, E. H. Scofield, J. H. Marten, Jr., A. N. Lundquist and Eug. Spence.

Mr. Avery announced the death of Mr. W. D. Van Duzee, an honorary member of the Club.

The following committee was appointed to draft suitable resolutions: Messrs. Redfield, Hoag and Sublette.

The program of the evening was then taken up. Mr. Francis Henry delivered a paper on "Changing the Course of Bassett's Creek through the Lakes and Minnehaha Falls." Discussion followed by Messrs. Cooley, Ilstrup, Sublette, Hoag, Loring, Fanning and Nutter. It was the general opinion of all speakers that, while the scheme appeared to be quite feasible, there were a great many difficulties to be taken into account, and that a very careful consideration should be given the subject before action was taken.

The hour being late, the remainder of the program, a paper also by Mr. Henry, on "Rice Irrigation and Culture in Texas and Louisiana," was postponed.

J. B. GILMAN, *Secretary.*

170TH MEETING, MINNEAPOLIS, MINN., DECEMBER 5, 1903.—A special meeting of the Club was held for the purpose of visiting the plant of the Minnesota Sugar Company. About one hundred members and friends availed themselves of the opportunity, assembling at Voegli's drug store, proceeding by car to St. Louis Park, where the plant is situated. The party was received by the President of the Company and his associates, and was shown through the works. The various processes of manufacture and purification by which granulated sugar is obtained from the beet were explained and shown, proving of great interest to those present.

J. B. GILMAN, *Secretary.*

Engineers' Club of St. Louis.

570TH MEETING, ST. LOUIS, MO., DECEMBER 2, 1903.—The meeting was held at the Club Rooms, 709 Pine Street, at 8.15 P.M.; President Van Ornum in the chair. Present thirty-two members and no visitors.

The first order of business was the nomination of additional candidates for office. None were made.

It was then moved, seconded and carried that nominations be closed.

In accordance with Article V, Section 1, of the Constitution, this was the annual meeting, and reports were read by the following officers and committees of the Club: Executive Committee (written by the President), Secretary, Treasurer, Librarian, Members of Board of Managers of Association of Engineering Societies, Members of Governing Board of Associated Technical Clubs, Committee on Smoke Abatement, Entertainment Committee (oral by the chairman of committee), Program Committtee.

All of these reports were ordered filed except that of the Treasurer, which was referred to the Executive Committee for auditing.

The Committee on Affiliation of Engineering Societies made a partial report through Mr. A. L. Johnson, chairman.

The Committee on Exposition Affairs and the Committee on Resolutions on the death of Professor Johnson were not ready to report.

Mr. Wm. H. Bryan announced the death of Mr. Geo. W. Fisher, a charter member of the Club.

The chair reported that in accordance with the request of the Hon. Rolla Wells, Mayor of St. Louis, the Engineers' Club membership and friends had contributed $124.90 to help defray the expenses of a suitable gift to the battleship "Missouri."

Mr. R. H. Phillips extended an invitation to the Club to visit the World's Fair Grounds at some time in the near future.

There being no further business the meeting adjourned.

H. J. PFEIFER, *Secretary.*

